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ERRATUM

D. P. Middaugh and J. M. Shenker. 1988. Salinity Tolerance of Young Topsmalt, *Atherinops affinis,* Cultured in the Laboratory. California Fish and Game, 74(4):232–235.

Page 233, line 17: Wet weights should read 0.0321 and 0.0382 g., not 0.321 and 0.382 as reported.

Calif. Fish and Game 75(4): 188–203 1989

LIFE HISTORY OF ANADROMOUS COASTAL CUTTHROAT TROUT IN SNOW AND SALMON CREEKS, JEFFERSON COUNTY, WASHINGTON, WITH IMPLICATIONS FOR MANAGEMENT [1]

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Upstream and downstream migrations of anadromous coastal cutthroat trout adults, sub-adults, and smolts were trapped and enumerated at Snow Creek Research Station between 1975 and 1985. Survivals of adults and sub-adults in freshwater were calculated as well as the survival of smolts in saltwater. Results were then compared with values generated from other studies.

The anadromous cutthroat in Snow and Salmon creeks represent a late-entry stock with upstream migration peaking between January and April. Overwinter survival of adults and sub-adults in freshwater ranged from 22.2% to 76.9% and appeared related to winter temperature and flow regimes in the stream. Marine survivals from smolt to first return to freshwater were too low to maintain the maximum smolt population observed.

INTRODUCTION

The cutthroat trout, *Oncorhynchus clarki,* is a polymorphic species with 10 named and 4 unnamed subspecies (Trotter 1987). The coastal cutthroat, *O. c. clarki,* ranges from northern California to southeastern Alaska (Hart 1973) and exists in fluvial, adfluvial, and anadromous forms. These forms can occur sympatrically and allopatrically within a given watershed. Studies by Michael (1983) suggested sympatric resident and anadromous populations in Salmon Creek, Jefferson County, Washington, were reproductively separate. June (1981) documented the presence of anadromous cutthroat spawning and rearing sympatrically with resident cutthroat in Bear Creek, a small stream in Jefferson County on the western Olympic Peninsula of Washington State.

In recent years, angler effort directed at anadromous cutthroat trout has increased and biologists have become concerned about the health of impacted populations (DeShazo 1980). In addition, limited research had been done on anadromous cutthroat, providing incomplete information on which to base management decisions. The Washington Department of Wildlife (WDW) (formerly Washington Department of Game) established a field station at Snow Creek in 1976 which subsequently provided an opportunity to obtain life history data on anadromous and resident cutthroat trout. This paper summarizes anadromous cutthroat trout data collected at the facility from 1976 to 1985. Results are compared with other studies and analyzed with regard to their management implications.

STUDY AREA, SALMONID POPULATIONS, AND MANAGEMENT HISTORY

Snow Creek and Salmon Creek are located on the northern portion of the Olympic Peninsula and drain into the Strait of Juan de Fuca (Fig. 1). Prior to

[1] Accepted for publication June 1989.

settlement of the area, Snow Creek was a tributary of Salmon Creek with the junction occurring just downstream of the present trap site on Salmon Creek. The lowermost kilometre (km) of Snow Creek has been channelized and the stream "moved" to the eastern side of the valley. From the air, Snow Creek's original channel is still visible in the pasture between the two creeks. Snow Creek still joins Salmon Creek in the intertidal area during low tides. At flows exceeding about 10 $m^{3/s}$, Snow Creek re-establishes some direct contact with Salmon Creek by crossing the pasture in what remains of the old channel bed. Snow and Salmon creek's watersheds are estimated to contain 53 km^2 and 49 km^2, respectively. Between 1 January 1977 and 31 December 1980, Snow Creek's average instantaneous discharge was estimated to be 0.33 $m^{3/s}$ and ranged from 0.02 to 12.76 $m^{3/s}$. During the same period, Salmon Creek had a mean discharge of 0.16 $m^{3/s}$ with a range of 0.02 to 6.85 $m^{3/s}$. The difference in discharge appears related to rainfall patterns caused by the Olympic Peninsula rainshadow.

Andrews Creek, the major anadromous zone tributary of Snow Creek, flows through 26 ha Crocker Lake which is located about 1 km above the juncture of the two streams (Figure 1). Prior to development of the area, Crocker Lake had no natural outlet (WDW files), and Andrews Creek flowed into Leland Lake, a tributary of the Little Quilcene River and ultimately to Hood Canal. Angler creel checks by WDW show that coho salmon, *O. kisutch,* juveniles are present in Leland Lake, indicating that the lake is presently available to anadromous fish. Consequently, upper Andrews Creek may have supported anadromous fish, including cutthroat, prior to its merger with the Snow Creek system.

Snow and Salmon creeks contain steelhead, coho, cutthroat, and chum salmon, *O. keta.* Michael (1983) found sympatric anadromous and resident stocks of cutthroat in the headwaters of Salmon Creek. Cutthroat were also present in the area occupied by coho and/or steelhead in both systems, and some may have been resident.

Brook trout, *Salvelinus fontinalis,* have been introduced into both watersheds and have established reproducing populations. These populations are most abundant in the headwaters of both streams, and are rarely present in the anadromous zones of either system. The headwaters of Andrews Creek is the only area where brook trout comprise more than 10% of the trout population.

Anadromous cutthroat trout in Snow and Salmon creeks are the late-entry variety as defined by Johnston and Mercer (1976). Late-entry cutthroat generally enter freshwater in winter or spring while early-entry fish enter freshwater as early as August. In Puget Sound, the early-entry stocks are generally associated with major river systems and late-entry stocks are generally associated with small, independent drainages. For purposes of discussion, there are two types of upstream migrating fish: subadults and adults. Subadults are fish which are returning to freshwater but will not spawn. These fish are often referred to as being on a "feeding" run. Adults are sexually maturing fish which will spawn within a few months. Two types of outmigrating juveniles are defined. The first, referred to as parr, consist of those fish with "stream" or "resident"-type coloration; the second are smolts, characterized by at least some silvery coloration and faded parr marks.

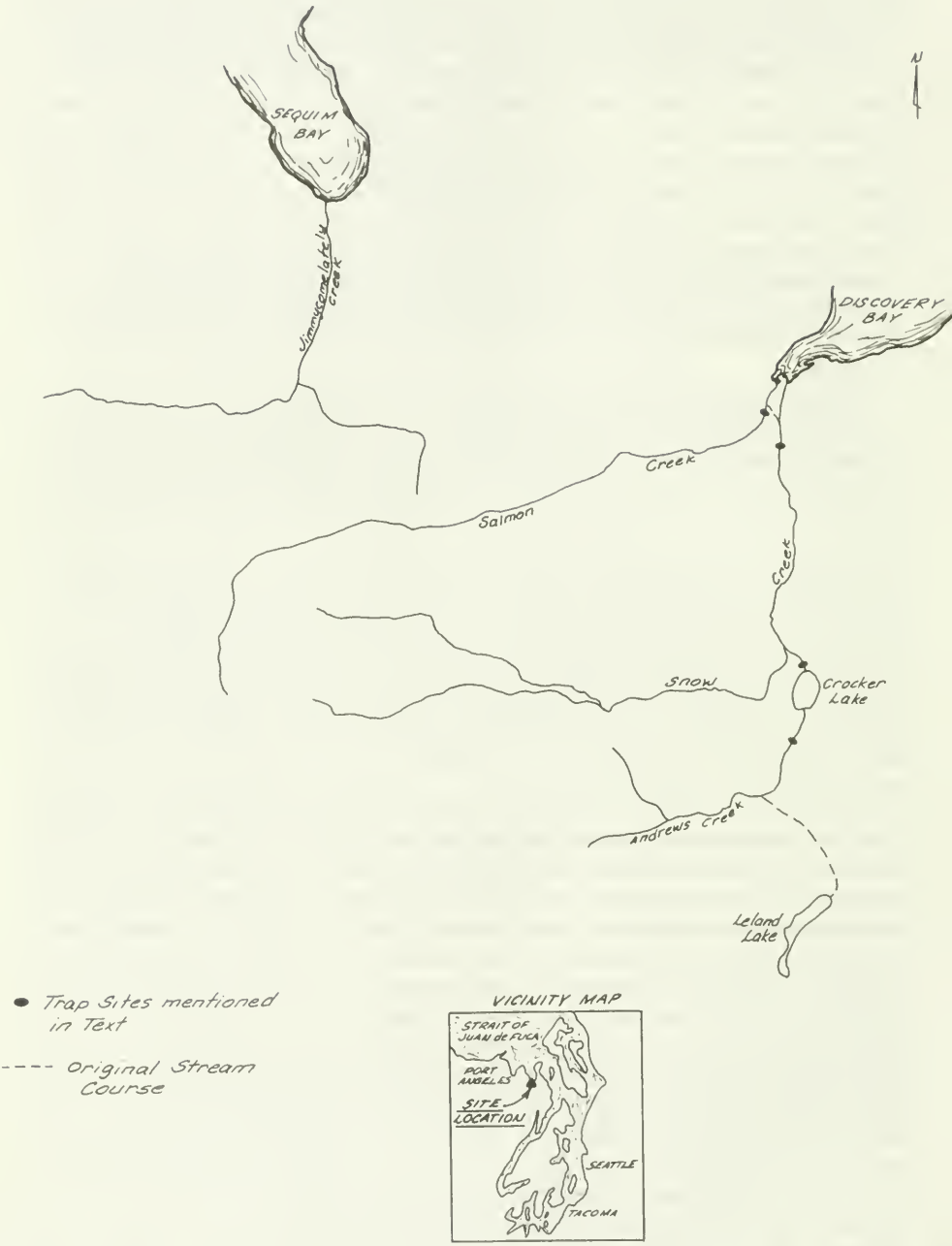

FIGURE 1. Map showing location of main study streams and trap sites.

Crocker Lake is managed for a put-and-take trout fishery. This fishery is maintained by annual stocking of hatchery-reared rainbow trout prior to mid-April. The remainder of the Snow and Salmon creek watersheds have been closed to angling since 1977.

METHODS

Between December 1976 and December 1977, temporary traps were installed near the mouths of Snow and Salmon creeks which provided partial counts of migrating fish (Figure 1). Temporary traps were replaced by permanent upstream and downstream fish traps in 1977. These traps were designed to capture fish greater than 300 mm fork length (FL) year-round and fish greater than 50 mm FL when smolt trapping screens were installed (generally March through August). Each spring, through 1981, a trap was operated on lower Andrews Creek, the outlet of Crocker Lake. During March and April 1977 a trap was also operated on upper Andrews Creek, the inlet to Crocker Lake. These traps were designed to trap all trout greater than 50 mm FL. No estimates of trap efficiencies were generated, and the number of fish captured, therefore, represents a minimum count. Loch et al. (1988) estimated trap efficiency for smolts at the Snow Creek trap as ranging from 90% to 100%. The method employed involved transporting marked smolts upstream of the trap and recording the proportion of marked smolts recaptured. The method employed did not document that marked fish actually passed through the trap, only that some marked fish were not recaptured. No accounting was made for delayed handling mortality or predation.

Cutthroat trout juvenile outmigrants captured in Snow and Salmon creeks' traps were measured to the nearest 1 mm FL, and a subsample was weighed to the nearest 0.1 g wet weight.

All outmigrants (juveniles, subadults, and adults) trapped were given a distinctive mark. Different marks were applied to outmigrants from Snow and Salmon creeks. Marks were changed annually to avoid confusion when fish were recaptured. Marks used were a combination of maxillary clips, pelvic fin clips, or freeze brands. These were applied so that each fish was identifiable as to year and stream of initial marking.

Cutthroat captured as upstream migrants were measured to the nearest 1 mm FL, weighed to the nearest 1 g wet weight, examined for marks, and tagged with a numbered monel-metal mandible tag. The sex and degree of maturity of the fish were determined by external examination. The same procedure was employed for downstream migrating adults and subadults.

Scale samples were collected from a subsample of cutthroat captured in the headwaters of Salmon Creek, a subsample of all cutthroat captured as outmigrants at the Snow and Salmon Creek traps, and from all upstream migrants captured.

The survivals in this study could be biased downward by at least six factors. First, the smaller fish that emigrated may not have been smolts. Giger (1972) demonstrated that a 4 to 5 g cutthroat could, when forced, adapt to 30‰ saltwater. The smallest presumed volitional outmigrant reported in Michael (1983) was 106 mm FL and 12.0 g in weight. Autumn electrofishing surveys downstream of the traps captured few cutthroat which had been marked as outmigrants. Consequently, the majority of cutthroat marked at the traps did not

remain in the creek and were of sufficient size to be able to physiologically adapt to saltwater. Second, stress involved in handling could have induced higher than normal mortality. From 1977 through 1979, an unbuffered anesthetic solution of MS-222 was used. Allen and Harmon (1970) showed an unbuffered solution could be acidic, causing irritation to the fish. However, the solution was buffered from 1980 onward with no apparent improvement in survivals. Third, the presence of the traps may have caused a delay in upstream migration and exposed the fish to increased predation. The Salmon Creek trap was a favored fishing area for great blue heron, *Ardea herodias;* numerous adult cutthroat had fresh stab wounds. Fourth, a sport fishery targeting on cutthroat occurs in Discovery and Sequim bays. No systematic harvest information was collected and no tagged fish were reported, but conversations with local anglers suggested harvests could have been substantial. Fifth, one fish was documented to have entered a completely different stream for overwintering. More fish probably did this resulting in the counts of marked fish returning to Snow and Salmon creeks being minimum. Finally, fish may have overwintered downstream of the traps. All of these factors may have contributed to the low survivals calculated. It is not possible to quantify the contribution of each factor.

Beginning in 1980, trap operations were reduced, resulting in collection of an unknown fraction of the cutthroat migration, especially upstream migrating fish.

RESULTS

Trapping of outmigrant juvenile cutthroat for all streams occurred generally from March to July, peaking during May and coinciding with the outmigration of steelhead and coho. Numbers of fish varied during eight years of trapping and also varied between creeks (Table 1). Snow Creek smolt numbers were consistently low, ranging from 8 to 36. A trap operated in upper Andrews Creek in the spring of 1977 caught 217 cutthroat which were migrating downstream; two of these were recaptured at the lower Andrews Creek trap after passing through Crocker Lake. Each year some cutthroat were trapped at lower Andrews Creek and a few of them were later captured at the Snow Creek trap (Table 2). The cutthroat smolt outmigration for Salmon Creek ranged from 7 to 635. Most of the outmigrants from both systems, as determined by analysis of scales, were age two. Electrofishing in September 1979 downstream of the Salmon Creek trap found four cutthroat out of 635 which had been marked as outmigrants, indicating almost no cutthroat moving downstream through the trap remained in the system.

Marine survivals to first return to freshwater for marked fish were calculated for cutthroat migrating from each creek and returning to either trap (Table 1). Survival of smolts from Snow Creek (measured from outmigration to first return to a trap) ranged from 13.9 to 21.7%; for Salmon Creek it ranged from 1.8 to 4.3%. It is assumed (Giger 1972) that cutthroat do not overwinter in saltwater although some of the scale samples showed no evidence of a slowing of growth associated with residence in freshwater.

Survival of marked adults and subadults in freshwater ranged from 22.2 to 76.9% (Table 1). The mean survival for all years was 61.7% for Snow Creek and 40.6% for Salmon Creek. The lower annual survivals were associated with winters of low temperatures and/or low stream flows. Three fish were observed to have oversummered in the Snow Creek system.

TABLE 1. Adult and Smolt Numbers and Survivals for Salmon Creek and Snow Creek Anadromous Cutthroat Trout.

Brood year	Adults marked			No. smolts 2 years later	Number of marked upstream migrants recaptured in trap	Survival outmigration to first return
	Up	Down	Survival in freshwater			
				Salmon Creek		
1975–1976	–	–	–	635	27	.043
1976–1977	7 [1]	3	.375	178	6	.034
1977–1978	56	27	.482	225	4 [2]	.018
1978–1979	27	6	.222	62	–	–
1979–1980	15	7	.467	27	–	–
1980–1981	12	3	.250	94	–	–
1981–1982	–	–	–	47	–	–
1982–1983	–	–	–	7	–	–
				Snow Creek		
1975–1976	–	–	–	26	5	.217
1976–1977	4 [1]	2	.500	36	5	.139
1977–1978	16	11	.688	27	4 [2]	.148
1978–1979	14	6	.429	11	–	–
1979–1980	13	10	.769	18	–	–
1980–1981	–	–	–	13	–	–
1981–1982	–	–	–	12	–	–
1982–1983	–	–	–	8	–	–

[1] Partial trapping.
[2] Count complete through July 1981.

TABLE 2. Salmonids Captured at Lower Andrews Creek Trap.

	Rainbow					Cutthroat		Re-trapped at Snow
Year	Stocked	Emi-grants	Percent	Coho	Steelhead [1]	Adults	Juveniles	Creek [2]
1977.....	10,000	56	0.6	1,147	47	8	15	0
1978.....	8,000	148	1.9	209[1]	151	Unk.	9	3
1979.....	6,500	76	1.2	1,002	42	Unk.	6	2
1980.....	6,500	19	0.3	677	60	2	16	2
1981.....	6,500	24	0.4	267	25	0	4	Unk.
Mean.....	7,750	64	0.9	660	65	–	10	–

[1] No spawning observed upstream of trap site, emigrants are result of immigration from Snow Creek.
[2] Partial trapping at Snow Creek.

Relatively few subadults and adults marked as outmigrants were captured as upstream migrants (Table 1). One subadult, marked as an outmigrant in Salmon Creek, was recaptured in Jiimmy-Come-Lately Creek, Clallam County (Figure 1). This creek drains into the southern end of Sequim Bay and represented a minimum marine migration of 33 km. This was the only marked cutthroat reported captured outside of the Snow or Salmon creek watersheds. There was substantial "straying" between creeks. Forty percent (40%) of Snow Creek origin fish and 30% of Salmon Creek origin fish were initially recaptured in the other creek. Most of these fish were subadults. Some were mature adults. One adult migrated out of Snow Creek in the spring, crossed the estuary to Salmon Creek, and went upstream to spawn.

Age classifications are preliminary (P. Knudsen, WDW scale analyst, pers. comm.) since there were few known-age, known-migration-pattern fish from which to establish points of reference for interpreting scales. Consequently, life history patterns were combined into broad classifications of first, second, third, or fourth return to freshwater (Table 3). By way of comparison, age classifications assigned to Stillaguamish River anadromous cutthroat are included (Johnston, 1979). The Stillaguamish fish are an early-entry stock; note the differences in size between the two stocks, with Snow and Salmon creek fish being generally larger at a given age/life history stage.

TABLE 3. Age Analysis for Anadromous Cutthroat Captured in Snow and Salmon Creeks and to Stillaguamish River.

Category	n	Mean	Range	Remarks
First Return				
Stillaguamish.....	88	276	155–356	Some fish immature, non-spawners re-
Show/Salmon.....	43	303	203–438	ferred to as "feeders."
Second Return				
Stillaguamish.....	12	361	305–420	All fish in spawning condition.
Snow/Salmon.....	17	402	263–485	
Third Return				
Stillaguamish.....	2	348	308–388	All fish in spawning condition.
Snow/Salmon.....	2	460	420–500	
Fourth Return				
Stillaguamish.....	1	400	———	All fish in spawning condition.

Coho, steelhead, and cutthroat make extensive use of Crocker Lake and/or upper Andrews Creek (Table 2). The Andrews Creek system, both upper and lower reaches, presently serves as spawning and rearing area for coho. Adult

coho ascend the upper creek after freshets, although low flows in some years deny access to upper Andrews Creek. Cutthroat kelts have been captured at the lower Andrews Creek trap; spawning locations have not been determined. No steelhead spawning has been observed in the system and no steelhead juveniles have been collected during regular electrofishing sampling in the upper creek. The upper creek supports a good population of cutthroat, some of which are migratory. Steelhead and coho juveniles do migrate upstream from Snow Creek into Crocker Lake, apparently to overwinter. Recently, the culvert immediately upstream of the confluence of Snow and Andrews creeks was replaced. The new culvert is at stream level (there is no drop between creeks) which will allow easier access to Crocker Lake by Snow Creek fish.

DISCUSSION

The observed mean freshwater survival for adults and subadults in Snow and Salmon creeks was similar to that reported for Minter Creek (Johnston and Mercer, 1976) and Sand Creek (Sumner, 1962). The variation between years appears to be a function of the winter stream environment. In winters of low stream flow and/or extreme cold, survival was generally lower (Table 4). Since many cutthroat streams are small, adverse climatic conditions may exert more pressure than on larger streams. Alterations which exacerbate environmental fluctuations such as removal of streamside and instream cover, channelization, or changes in flow and runoff regimes probably have a negative effect on the survival of cutthroat adults in freshwater. Studies reported by Moring and Lantz (1975) show that certain logging methods which removed streamside cover caused stream temperatures and flows to have wider fluctuations than would occur in the undisturbed stream. Studies conducted on Carnation Creek, a small stream on Vancouver Island, British Columbia, demonstrated that overwinter carrying capacity for coho could be severely reduced by clear-cut logging (Tschaplinski and Hartman, 1983). In addition, Holtby and Hartman (1982) concluded that logging in a watershed led to gradual but accelerating changes in stream morphometry. These changes, especially those associated with freshet, should reduce the ability of a stream to support overwintering salmonids. McCrea's (1984) discussion of the deterioration of small stream habitats protected in accordance with Washington State law demonstrates the need to determine niche requirements of fish in these small streams and develop methods and regulations to protect, restore, and manage the entire terrestrial and aquatic resource complex.

The marine migration patterns observed in this study agree with studies in Alaska (Jones, 1979) that indicate some streams were used as overwinter habitat only, with the fish spawning in other streams. Snow Creek is substantially larger than Salmon Creek and the lower reaches have many deep holes with root wads, undercut banks, and/or debris piles. This sort of environment may have offered more protection to overwintering fish as survival of adults and subadults in Snow Creek was generally higher than that observed in Salmon Creek. At spawning time, the adults return to their home stream.

The estimated marine survivals (1.8–21.7%) from smolt to first return for both Snow and Salmon creeks are generally low. Giger (1972) reported 20–40% survivals from smolting to first return for Oregon stocks not exposed to

TABLE 4. Mean Daily Water Temperature, Mean Instantaneous Discharge for November through February and Survival of Adult and Subadult Cutthroat in Freshwater, 1976–1980.

Year	*Mean daily water temperature (°C)*		*Mean daily discharge (cms)*		*Survival of adult and subadult cutthroat in freshwater*	
	Snow Creek	*Salmon Creek*	*Snow Creek*	*Salmon Creek*	*Snow Creek*	*Salmon Creek*
1976–1977[1]	4.7	4.0	0.14	0.07	0.500	0.375
1977–1978	5.2	4.7	0.75	0.26	0.688	0.482
1978–1979	2.8	2.8	0.38	0.23	0.429	0.222
1979–1980	0.8	0.7	0.67	0.58[2]	0.769	0.467

[1] January and February only; November and December measurements unrecorded but drought conditions prevailed.
[2] January and February only.

a fishery, and Jones (1978) reported a survival of 17% in an Alaskan stock he considered to be overharvested.

Brook trout in the three watersheds present a potential problem to the native salmonids. Thurow and Bjornn (1978) showed brook trout, when once established in their preferred habitat, were not displaced by a cutthroat population which was otherwise increasing under full protection. Cunjack and Green (1984) documented the brook trout's ability to dominate rainbow trout in slower velocity waters. In the present study, brook trout preferred the slower sections of the creeks; a habitat similar to the headwater cutthroat habitat in Salmon Creek, the lower 6.5 km of Snow Creek and most of Andrews Creek. Once established, a brook trout population could reduce the available habitat for cutthroat, steelhead, and coho with a resultant loss in smolt production. Brook trout are presently abundant only in Andrews Creek. Brook trout are present in the anadromous zone portion of upper Andrews Creek but numbers fluctuate widely between years and few of the fish are older than age 1.

Michael (1983) observed the sympatric rearing of resident and anadromous cutthroat stocks in Salmon Creek. As a migratory stock declines, it will be replaced in the stream by resident fish. June (1981) measured a 57% decline in age 2+ cutthroat in his study stream between April and July, attributing this to the smolt outmigration which occurred in May and June. At the same time, Penny Creek, a stream with only resident cutthroat (WDG, 1980), the age two (and older) component of the population had a stable population number from year to year. It is not known if anadromous stocks could reestablish themselves following a decline, since Thurow and Bjornn (1978) suggested resident cutthroat had replaced over-exploited migratory cutthroat in St. Joe River (Idaho) tributaries. They were concerned about the ability of the migratory fish to establish their original distribution without human intervention. Reestablishment of depleted anadromous cutthroat stocks may require intervention to remove established resident populations of cutthroat and/or brook trouts.

Adult populations of anadromous salmonids with extended periods of freshwater rearing (steelhead and cutthroat trout, coho salmon, etc.) are controlled, to a large degree, by the number of smolts produced. Several studies have suggested limits for smolt production by stream-rearing anadromous salmonids (Salo and Bayliff 1958; Seiler et al. 1981; M. Chilcote, WDW biologist, pers. comm.; and ongoing Snow Creek studies) in a given system. Sekulich (1980), in a study of chinook salmon, *O. tshawytscha,* in Idaho, concluded that seeding rate governs fish density until populations reach a size limited by other factors, and his data suggest each stream had a different rearing potential, consequently, direct comparison of smolt numbers between streams is probably invalid. As an example, using coho in some Western Washington streams, Snow Creek has an estimated accessible length of 12.9 km, Minter Creek 20.8 km, and the Skykomish River (and tributaries) upstream of Sunset Falls 188 km. Coho smolt production measured for these streams was approximately 8,000 (620/km), 30,000 (1,450/km) and 200,000 (1,050/km) respectively. For cutthroat, a watershed may include resident and anadromous stocks and the interaction between the two will affect smolt numbers, further complicating estimation of a system's capacity to produce cutthroat smolts. Smolt production is related to various habitat parameters, including (but not limited to) streamflow, overwinter cover, food supply, water chemistry, stream gradient,

and extent of spawning. Smolt production potential is probably a matrix of these (and other) variables.

The WDW has a program to screen the outlets of certain lakes. This program was designed to retain stocked trout in the lake for harvest by sport fishermen. The presence of the lower Andrews Creek trap allowed evaluation of this practice. Screens have had a dramatic effect on migratory fish which used the waters upstream of them, denying access to a number of species, generally coho, steelhead, cutthroat and, occasionally, sockeye, *O. nerka,* and chinook. The savings realized by screen operation versus the loss in migratory fish production make the continuation of screening questionable. For example, Crocker Lake coho smolts (Table 2) contributed about 70 fish per year to the sport and commercial fisheries (R. Lincoln, Washington Department of Fisheries (WDF) biologist, pers. comm.). Screens would have kept 64 trout in the lake with some fraction harvested. In 1983, WDF stocked coho fry downstream of screens operated at Deep Lake in Thurston County. Due to screen design, fry were able to emigrate into the lake and rear. In 1984, over 33,000 smolts were trapped as they left the lake (in addition to many taken in the trout fishery). At the same time, less than 400 trout were trapped (D. Seiler, WDF biologist, pers. comm.). From these two examples, it appears the strain of rainbow trout used to stock lowland lakes in western Washington is essentially nonmigratory and will remain in the lake, at least during the March through June smolt migration period. At the same time, the lakes have the potential to rear and overwinter substantial populations of anadromous salmonids whose contributions to all the fisheries will far exceed the contribution of the "saved" resident trout. Access to these lakes for spawning, rearing, and overwintering serves to increase smolt production potential for a system above that available in the fluvial habitats. Additionally, inlet streams offer additional fluvial spawning and rearing habitat.

MANAGEMENT IMPLICATIONS

Harvest Management

The value of a life history study is development of management plans which utilize generated data. Management scenarios can then be compared for their relative effects on a population. Studies by Johnson and Bjornn (1978) demonstrated for westslope cutthroat, *O. c. lewisi,* that a restrictive bag limit (three fish) which did not protect females until they had spawned once (by use of minimum size and gear restrictions) did not result in an increased population size while a stream with a three-fish limit and necessary gear and minimum size restrictions showed a four-fold increase in 6 years. The success of this type of management for resident coastal cutthroat was suggested in the Penny Creek study (Washington State Game Department, 1980). In that study, resident cutthroat appeared to adequately seed the stream in that the age 2 and older population was numerically stable despite variable levels of age 0 and age 1 fish. Penny Creek, with a sport fishery, had 2.2% fish greater than 150 mm FL (the minimum legal size for harvest in Penny Creek) in October samples, while the resident portions of Snow and Andrews creeks (streams with no fishing) had about 7.5% of the population greater than 150 mm FL when sampled in late September, indicating a substantial removal of larger fish from Penny Creek.

Since smolt production is controlled by habitat once some threshold minimum seeding has been achieved, it is necessary to define a method to regulate the fishery to obtain this escapement. Johnson and Bjornn (1978) determined that an easily defined benchmark for adequate escapement of resident inland cutthroat would be to allow all females to spawn at least once prior to entry into the harvest. Initially, this same method should be applied to anadromous cutthroat. To determine this, one needs to know size at maturity for the stock in question. As can be seen in Table 3, the mean length of aged Snow and Salmon Creek fish that were on their second return to freshwater and would definitely spawn was 402 mm while the same group shows a mean FL of 361 mm for Stillaguamish River stocks. Since there are differences in size at various ages for early- and late-entry cutthroat stocks, it will be necessary to determine the age/length relationship for each stock to be managed and the composition of the stocks in an area proposed for regulation prior to implementation of regulations. For example, a minimum size of 420 mm FL may adequately protect all stocks in saltwater but would provide "too much" protection to an early-entry stock if it were applied to a freshwater fishery.

Habitat

Had screens been in operation on Crocker Lake (as they were for a number of years) during 1977 to 1981, an average of 64 rainbow trout would have been saved for potential harvest in the Crocker Lake trout fishery (Table 2). The cost, in terms of actual lost harvest of other fish, was much larger. The coho smolts would have contributed about 70 fish to the sport and commercial harvest (R. Lincoln, WDF biologist, pers. comm.). The steelhead and cutthroat would also provide some fish to the sport fishery. The observation of both steelhead and coho actively seeking Crocker Lake for overwintering demonstrates a way to increase a system's smolt production potential above that possible by considering fluvial habitats alone.

The effects of development, whether logging, road building, subdivision, or some other alteration of the habitat, can have serious consequences for cutthroat. Changes in temperatures and flow regimes will probably lower both the carrying capacity for juveniles and the ability of the stream to support pre-spawning adults in winter. Improperly designed and/or maintained culverts will block access to portions of a stream; logging debris left in a stream may have the same effect. Cutthroat make extensive use of small streams, some of which appear to be minor. In some cases, these streams have had all riparian vegetation removed during logging operations in accordance with accepted forest practice restrictions in place at the time. Complete exposure of the creek was probably detrimental to the trout present.

Genetics

Brown (1983) and Tave (1984) suggest a minimum reproducing population of 50 adults is necessary, in the short-term, to avoid inbreeding. They further believe a much larger breeding population, perhaps on the order of 500, is necessary for the population to survive and continue to evolve within its niche. By applying the survivals estimated by Giger (1972) and Sumner (1962) to the largest outmigration trapped at Salmon Creek, it would appear that the potential adult population, in the absence of a fishery, was in excess of 200 spawners.

Smolt outmigrations of less than 100 fish raise concerns about genetic impacts to the population and indicate that restoration programs will need to consider the consequences of allowing the population to decline to low levels prior to implementation of a recovery program. Population size considerations suggest streams such as Snow and Salmon creeks may be part of a larger "complex" which produced a reasonably sized spawning population. This suggestion is supported by the large proportion of returning adults and subadults which were not marked as outmigrants. Managers should not seek, for example, to restore only a part of the complex. The ultimate survival and health of Salmon Creek's cutthroat may rely on Snow, Eagle, and Contractors creeks (other Discovery Bay streams). Since at least one Salmon Creek origin cutthroat was observed in a Sequim Bay tributary stream, it is possible that the functional, interbreeding population spawned in a number of tributaries of the two bays. Electrophoretic examination and tagging studies of a large number of spawning populations will be necessary in order to identify the functional reproducing unit. Resource management history shows a number of situations where introductions of relatively few individuals resulted in large populations (striped bass, *Morone saxatilis,* and American shad, *Alosa sapidissima,* in California, pink salmon, *O. gorbuscha,* in the Great Lakes, and starling, *Sturnus vulgaris,* and house sparrow, *Passar domesticus,* in North America). Somehow, these small populations successfully "rebounded" from low parental population numbers and were able to adapt and evolve in their environment. Restoration of depleted cutthroat stocks will require an understanding of genetics of such small populations.

Research Needs

During the relatively short term of full staffing and funding of the Snow Creek studies, a significant amount of data was collected. It became obvious that to properly manage anadromous cutthroat, substantial additional study must be done. The questions raised below, which were identified during the study of cutthroat, are perhaps even more critical to the management of steelhead and Pacific salmon, species with substantially higher economic values. These studies need to be long-term, multi-generational in nature in order to test hypotheses over a wide range of biological and environmental conditions.

The streams in which cutthroat live are highly dynamic and, over time, the various species of fish found in them have evolved to optimally exploit certain niches. Changes to the watershed brought on by logging, fire, debris removal, barrier removal, out-of-channel water uses, hydroelectric development and even the preservation of "pristine" environments will affect the fish community. Recent studies on the effects of watershed manipulations have shown that the stream changes for an extensive length of time in an attempt to restabilize itself. In order to reasonably allocate, utilize, and protect the resources of a watershed, the species-specific niches must be determined. Initially, the niche of each organism in the undisturbed situation must be determined so that response to the intended changes can be estimated, quantified, and evaluated. Finally, the responses of the individual species must be integrated into a community assessment of impact. Although the final decision regarding use of the resources in a given watershed will undoubtedly be politically based, resource managers must be able to present objective analyses of benefit:cost to the decision-makers if they are to make reasonable decisions.

Of particular importance to management of any exploited species is the determination of the proper size for the reproducing population. It is necessary to determine at what level of escapement the maximum number of recruits to the harvest on a sustainable basis is obtained. This question becomes especially important for the management of commercially exploited species where each fish not caught is viewed as income out-of-pocket to the harvester and the local community. Salo (Univ. of Wash. professor, pers. comm.) observed for coho that increased escapement, above the threshold level, did not increase smolt numbers produced but did appear to increase the marine survival of the smolts, perhaps due to increased fitness. Quantification of this is critical to the determination of proper spawning escapement and must involve a long-term study to investigate a variety of escapement levels, in-stream flow conditions, and marine environmental conditions.

Each breeding population of cutthroat has evolved within a specific ecosystem and is somewhat different from neighboring cutthroat populations. The evolutionary process has produced unique responses to specific environmental conditions and if these fish are to continue to evolve in a changing environment, then they must have access to as many genetic options as possible. Consequently, it is necessary to understand just what is the breeding population, what size does it need to be, what is the straying rate, what is the effect of hatchery-origin fish on the gene pool, etc., in order to know just which populations should be part of a mangement plan.

SUMMARY

The upstream and downstream migrations of searun coastal cutthroat were monitored in two adjacent independent drainages in Western Washington. Counts of smolt numbers, survival from smolting to first return, and survival of subadults and adults in freshwater were made.

Survival of outmigrants from smolting to first return to freshwater ranged from 1.8 to 21.7%. Returning spawners were not sufficient to maintain the population in Salmon Creek, where the lowest marine survivals were observed. Survivals of adults and subadults in freshwater ranged from 22.2 to 76.9% and appeared related to winter water temperature and flow conditions.

The literature and studies on other Washington streams suggest a regulation which allows the population to spawn once prior to entry into a harvesting fishery will be able to maintain itself at the stream's carrying capacity for smolt production. There were indications that resident salmonids sympatric with the anadromous cutthroat may displace or replace anadromous stocks if the searun stock declines.

There were indications that current populations are low enough to cause concern about the loss of genetic diversity resulting in a handicapping of restoration efforts.

Finally, Needham (1938) recognized the need for research efforts. He said "One hindrance to the union of science with practical fish culture in recent years has been the lack of continuity of both program and personnel, and then shifting ideas or personnel have necessitated stopping such investigations at a moment's notice and usually before any concrete results have been obtained.

Insofar as the production efforts that may aid the fisheries management is concerned, it is continuity of both program and personnel that counts; we cannot make progress without both. Research is expensive; it is slow, and those who are going to employ it as a fact-finding method to aid in their problems must be willing to wait results." Secondly, the lack of personnel and funding has resulted in numerous studies and much data being unanalyzed and unreported. Moyle (1976) requested, in reference to life history studies in California, "Please, if you are going to undertake a life-history examination, aim to have your results published in a scientific journal." These two statements are applicable to any agency conducting resource research and should be considered prior to making the "commitment" to a long-term program. One of the justifications for program reductions is economy. It is false economy to conduct studies and then either reduce the staffing level or redirect efforts so that the studies are uncompleted, unanalyzed and/or unpublished. This leads to duplication and repetition of studies because people are unaware of former studies. This certainly cannot be a wise use of scarce funds or valuable natural resources. The desire to prevent needless duplication of studies was recognized by fisheries managers as early as 1948 (Pac. Mar. Fish. Comm. 1948). Forty years later, this is still a goal to be reached.

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LITERATURE CITED

Allen, J. L. and P. D. Harman. 1970. Control of pH in MS-222 anesthetic solutions. Prog. Fish. Cult., 36(2): 100.

Brown, A. M. 1983. Conservation genetics in Victoria. Fisheries Wildlife Service, Victoria, Australia, Resources and Planning Branch, Tech. Rept. Ser., No. 1. 50 p.

Cunjak, R. A. and J. M. Green. 1984. Species dominance by brook trout and rainbow trout in a simulated stream environment. Trans. Amer. Fish. Soc., 113:737–743.

DeShazo, J. J. 1980. Sea-run cutthroat trout management in Washington—an overview. Pages 1–17, *in* Sea-run cutthroat status report. Wash. Dept. of Game, Fish Mgmt. Div. Report 80-14.

Giger, R. D. 1972. Ecology and management of coastal cutthroat in Oregon. Fishery Research Report #6, Oregon State Game Commission. 61 p.

Hart, J. L. 1973. Pacific fishes of Canada. Bull. Fish. Res. Bd. Canada, 180:740 p.

Holtby, L. B. and G. F. Hartman. 1982. The population dynamics of coho salmon *(Oncorhynchus kisutch)* in a West Coast rain forest stream subject to logging. Pages 308–347 *in* Proceedings of the Carnation Creek workshop; a 10-year review. G. Hartman, ed. Nanaimo, B.C.

Johnson, T. H. and T. C. Bjornn. 1978. The St. Joe River and Kelley Creek cutthroat trout populations: an example of wild trout management in Idaho. Pages 39–47 *in* Proceedings of the Wild Trout-Catchable Trout Symposium. J. R. Moring, ed. Eugene, Oregon.

Johnston, J. M. 1979. Sea-run cutthroat: Stillaguamish River creel census (1978) and harvest limit recommendations. Wash. Dept. of Game. 42 p.

Johnston, J. M. and S. P. Mercer. 1976. Sea-run cutthroat in saltwater pens: broodstock development and extended juvenile rearing. Wash. Dept. of Game Federal Aid to Fish Restoration, Progress Report AFS-57-1. 92 p.

Jones, D.E. 1978. Life history of sea-run cutthroat trout. Alaska Dept. of Fish and Game. Anadromous Fish Studies, Completion Report, 1971–1977. Project AFS-42. 18(AFS-42-5-B): 78–105.

Jones, D.E. 1979. Development of techniques for enhancement and management of anadromous cutthroat trout in Southeast Alaska. Anadromous Fish Studies, Annual Performance Rept. 1977–1978. Project AFS-42. (AFS-42-6-B): 69–119.

June, J. A. 1981. Life history and habitat utilization of cutthroat trout *(Salmoclarki)* in a headwater stream on the Olympic Peninsula, Washington. MS Thesis, Univ. of Wash., Seattle. 116 p.

Loch, J. J., S. A. Leider, M.W. Chileote, R. Cooper, and T. H. Johnson. 1988. Differences in yield, emigration-timing, size, and age structure of juvenile steelhead from two small Western Washington streams. Calif. Fish and Game, 74(2):106–118.

McCrea, M.E. 1984. Upstream, downstream—why the state Forest Facilities Act is not protecting public resources. M.S. thesis, Wash. State Univ., Pullman. 119 p.

Michael, J. H., Jr. 1983. Contribution of cutthroat trout in headwater streams to the sea-run population. Calif. Fish and Game, 69(2):68–76.

Moring, J. R. and R. L. Lantz. 1975. The Alsea watershed study: Effects of logging on the aquatic resources of three headwater streams of the Alsea River, Oregon. Oregon Dept. of Fish and Wildlife, Fisheries Res. Rept. No. 9. 66 p.

Moyle, P.B. 1976. Inland Fishes of California. Univ. of Ca. Press. Berkeley, Calif. 405 p.

Needham, P.R. 1938. Trout streams. Holden-Day, Inc., San Francisco, Calif. 241 p.

Pacific Marine Fisheries Commission. 1948. Coordinated plans for management of the fisheries of the Pacific Coast. Pac. Mar. Fish. Comm. Bull., 1: 12–64.

Salo, E.O. and W.H. Bayliff. 1958. Artificial and natural production of silver salmon, *Oncorhynchus kisutch,* at Minter Creek, Washington. Research Bull. No. 4 , Wash. Dept. of Fisheries. 82 p.

Seiler, D., S. Neuhauser, and M. Ackley. 1981. Upstream/downstream salmonid trapping project, 1977–1980. Wash. Dept. Fish. Prog. Rept. 144. 197 p.

Sekulich, P. T. 1980. The carrying capacity of infertile forest streams for juvenile chinook salmon. PhD dissertation, Univ. of Idaho, Moscow. 156 p.

Sumner, F. H. 1962. Migration and growth of the coastal cutthroat trout in Tillamook County, Oregon. Trans. Amer. Fish. Soc., 91: 77–83.

Tave, D. 1984. Effective breeding efficiency: an index to quantify the effects that different breeding programs and sex ratios have on inbreeding and genetic drift. Prog. Fish. Cult., 46(4):262–268.

Thurow, R. F. and T. C. Bjornn. 1978. Response of cutthroat trout populations to the cessation of fishing in St. Joe River tributaries. College of Forestry, Wildlife and Range Sciences, Univ. of Idaho, Bull. 25: 35 p.

Trotter, P.C. 1987. Cutthroat: native trout of the west. Colorado Assoc. Univ. Press., Boulder, Colo. 219 p.

Tschaplinski, P. J. and G. F. Hartman. 1983. Winter distribution of juvenile coho salmon *(Oncorhynchus kisutch),* before and after logging in Carnation Creek, British Columbia, and some implications for overwinter survival. Canadian J. Fish & Aquatic Sci., 40(4): 452–461.

Washington State Game Department. 1980. Penny Creek coho planting study. Pages 70–84 in G. Garrison, ed. Steelhead program progress report, December 31, 1979.

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THE DISTRIBUTION AND DENSITY OF EELGRASS, *ZOSTERA MARINA,* IN TOMALES BAY, CALIFORNIA

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The total area of 37 eelgrass, *Zostera marina,* beds in Tomales Bay was 3.9 million m^2. Eelgrass beds were found to a depth of 12 ft (3.6 m) below mean lower low water.

Scuba was used to remove eelgrass from ¼ m^2 — quadrats in 16 eelgrass beds. Winter wet weight ranged from 0.5 to 1.9 kg/m^2.

A multiple linear regression of eelgrass density on eelgrass blade measurements was developed ($r = .78$).

INTRODUCTION

Eelgrass, *Zostera marina,* is the most abundant marine flora in Tomales Bay, California (Hardwick 1973). It is also the primary spawning habitat of Pacific herring, *Clupea harengus pallasi,* in the bay. The distribution and density (kg/m^2) of eelgrass are a critical part of annual Pacific herring spawning biomass estimates, which are used to manage the commercial herring fishery (Spratt 1981).

The distribution of eelgrass in Tomales Bay is determined annually with a recording fathometer as part of seasonal herring spawning-ground surveys. Generally, only the size of beds changed from year to year and not the location, but new beds have been discovered since the last distributional data were published (Spratt 1981). This report includes eelgrass distribution in the spring of 1988.

Vegetation density estimates in Tomales Bay have been made by removing vegetation from randomly placed quadrats with scuba (Hardwick 1973). The first vegetation density survey that targeted on eelgrass was a very limited scuba survey in 1975 (Spratt 1976). In 1976, the California Department of Fish and Game's Driving Safety Board (DSB) declared Tomales Bay off-limits to Department divers as a precautionary measure due to several white shark, *Carcharodon carcharias,* attacks on divers or surfers near the mouth of Tomales Bay.

Because of the importance of eelgrass density estimates for Tomales Bay herring management, the DSB approved the use of scuba for a one-time survey in 1986 of selected eelgrass beds. Eelgrass was removed from randomly placed quadrats, blade measurements were taken and acoustical data recorded to develop a correlation with density. Regression techniques were applied to the data and a multiple linear regression model was developed. In the future, required eelgrass parameters may be measured from the surface by boat and eelgrass density estimated without diving.

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Study Area

Tomales Bay is a long, narrow embayment, 19 km long and 0.8 to 2.4 km wide. It is located on the San Andreas Fault about 64 km north of San Francisco (Figure 1). The sediment in the northern half of the bay is composed of fine to course sand, while in the south part of the bay mud and muddy sand dominate (Deatwyler 1966). The greatest depth of the bay is 18 m (60 ft) but eelgrass was not found deeper than 3.6 m (12 ft) below mean lower low water. Eelgrass beds that are in the center of the bay are on shallow sand bars (Figure 1).

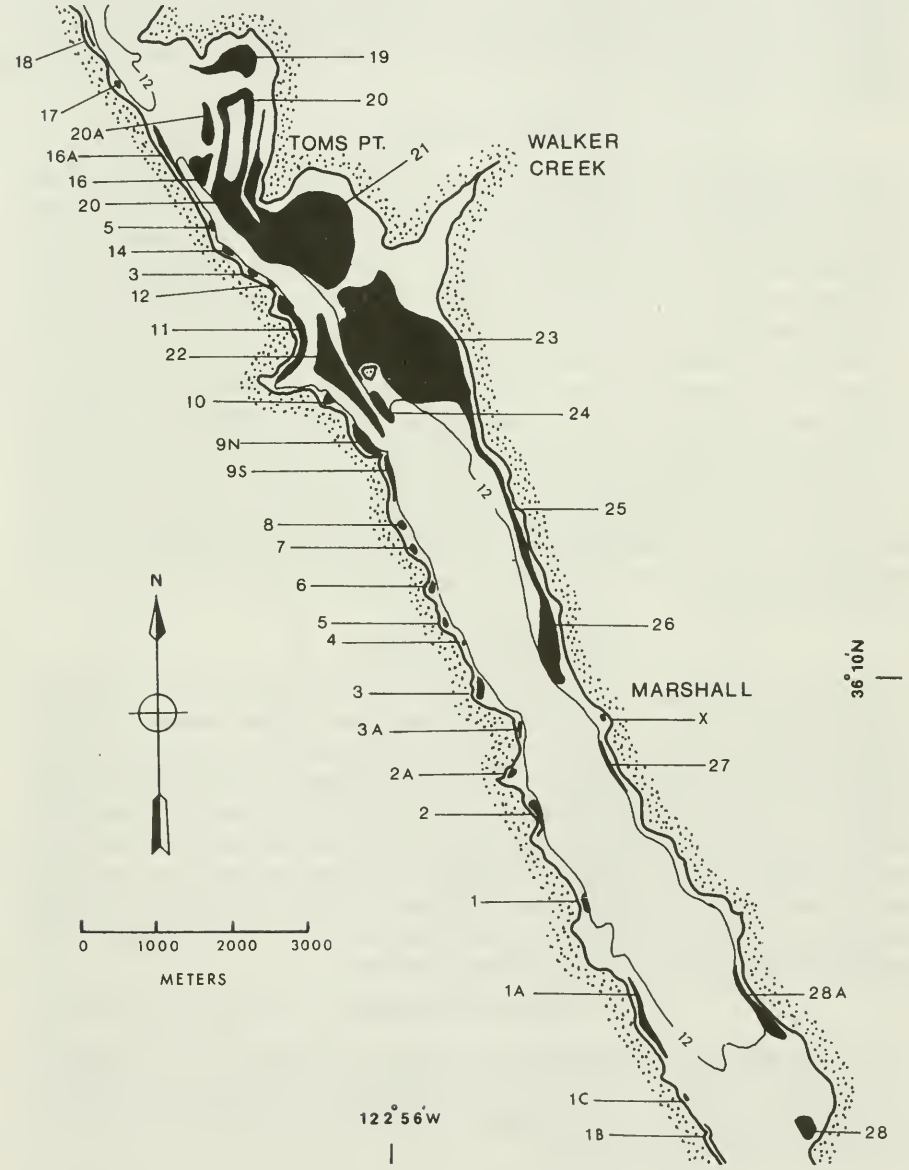

FIGURE 1. Numbered eelgrass beds in Tomales Bay, California, March 1988.

METHODS

Eelgrass Distribution

Eelgrass distribution in the winter of 1987–88 (Figure 1) was determined with a Lowrance Truline LRG-1510 recording fathometer and a vegetation sampler was used to verify that fathometer recordings were of eelgrass.

Area (m^2) of all definable eelgrass beds in Tomales Bay was measured in March 1987. The size of smaller beds was determined by locating the bed boundaries acoustically, marking the boundaries with anchored floats and measuring between floats. The boundaries of larger beds near Walker Creek (Figure 1) were marked on a navigational chart and area (m^2) was measured directly from the chart.

Eelgrass Sampling

The November 1986 survey was limited to relatively shallow eelgrass beds that were considered the safest areas for diving. Sixteen eelgrass beds from the southern half of Tomales Bay (Table 1) were sampled. Ten equally spaced transects were drawn perpendicular from shore through each bed. Three transects were then randomly selected from each bed, except bed X which had only one transect because of its small size. A $\frac{1}{4}$ m^2 — quadrat was placed in an area of 100% eelgrass bottom cover near the mid-point of each transect. All eelgrass was removed from each quadrat, placed in labeled plastic bags and stored overnight in an ice chest. The next day, eelgrass blades were trimmed from rhizomes, washed and damp dried before weighing. Wet weight was recorded to the nearest gram. Immediately after weighing, one eelgrass blade was randomly selected from each quadrat; the length (m) of the blade was determined and the width (mm) was measured 500 mm from the point where the rhizome was trimmed to standardized the location of the eelgrass blade width measurement.

Acoustical Transects

Acoustical recordings of eelgrass distribution were made by boat along the same transects. Tidal currents in Tomales Bay often caused eelgrass to lie flat against the bottom, making it difficult to locate eelgrass beds and determine the percent of the bottom covered by eelgrass. Therefore, acoustical data were obtained near slack water conditions on moderate high tides. The percent of bottom covered by eelgrass on each transect was measured from acoustical chart recordings (Figure 2). Transect length measurements began and ended at well defined bed boundaries. The total length of the recording within the eelgrass bed and the length of the recording not covered by eelgrass were measured, to compute percent eelgrass coverage.

Linear Relationship

The mathematical relationship developed in this paper is a variation of Maceina et al. (1984), in which linear relationships were developed between echo sounder recordings of submerged vegetation and samples removed by scuba or a circular core sampler.

TABLE 1. Eelgrass Measurements, and Wet Weight of Eelgrass Collected by Scuba from Tomales Bay.

Bed no.	*Transect no.*	*% bottom cover*	*Blade length m*	*Blade width mm*	*kg/m²*
1	1	100	1.07	9	2.0
	4	90	.93	8	1.2
	7	95	.79	9	0.9
1A	1	50	1.12	8	1.8
	4	90	.97	8	1.5
	6	80	.74	5	0.5
2	1	100	1.05	8	1.7
	4	50	1.13	10	1.7
	6	75	.98	8	1.3
3	6	75	.83	7	0.9
	8	100	1.10	10	1.7
	9	–	–	–	–
4	3	100	1.10	6	1.4
	4	100	1.03	8	1.6
	9	100	.67	7	1.1
5	1	80	.90	7	0.9
	3	90	1.07	9	1.0
	8	100	.92	8	1.6
6	4	100	1.07	9	1.4
	5	100	.95	7	1.2
	6	100	.70	6	.7
7	1	70	1.20	7	1.8
	3	100	.73	6	1.2
	4	100	1.20	7	2.5
8	3	90	1.43	10	2.5
	5	90	1.08	8	0.9
	9	100	1.10	9	2.2
9S	2	100	1.25	9	1.4
	3	100	1.30	8	2.7
	5	100	.75	7	1.2
9N	3	95	1.20	11	1.9
	4	95	1.23	10	2.7
	8	90	1.10	8	1.4
25	2	80	.65	8	1.1
	3	80	.57	7	1.1
	7	80	.55	7	1.1
26	1	100	.70	7	1.2
	5	80	.73	7	.8
	8	60	1.00	8	2.2
27	3	90	.95	9	1.0
	6	100	.70	8	.8
	9	100	1.20	10	1.7
28A	6	75	.55	6	.2
	7	75	.73	8	1.0
	8	75	.58	7	.6
X*	–	30	1.10	8	2.2

* Newly discovered eelgrass bed near Marshall.

Regressions were run using combinations of eelgrass blade length, width, and percent bottom cover estimates. The best regression model included only length and width variables and was represented by the following equation:

$$Y = a_l \text{ (length)} + a_w \text{ (width)} + b$$

where:

Y = kg eelgrass per m^2
a_l = slope of regression for length
a_w = slope of regression for width
b = Y intercept

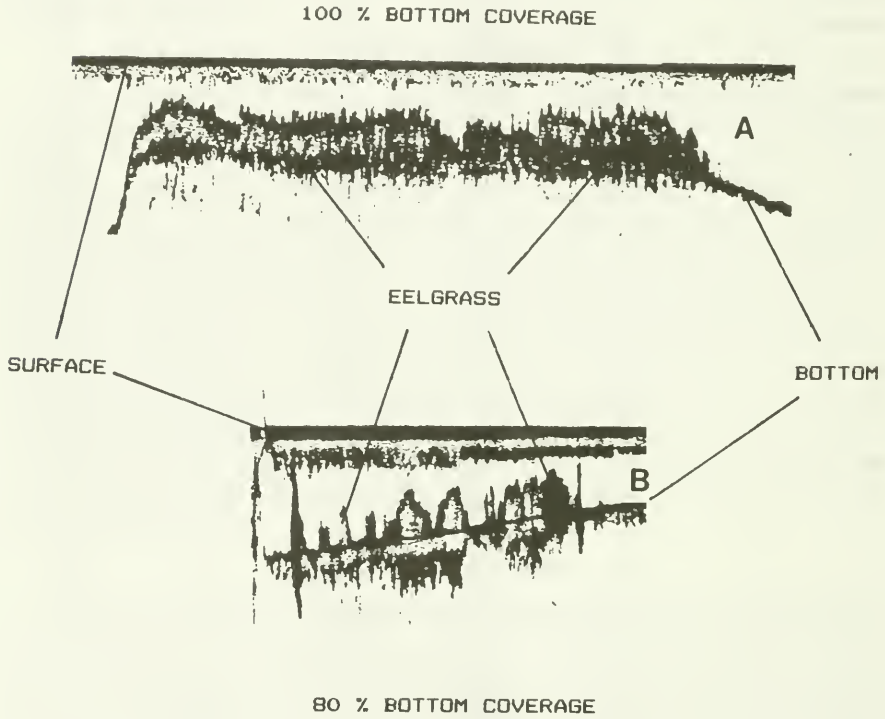

FIGURE 2. Acoustical chart recording of Tomales Bay eelgrass beds: (A) bed 22 with 100% bottom coverage; (B) bed 1A with 80% bottom coverage.

Eelgrass Density Estimates

There are 21 additional eelgrass beds in Tomales Bay that were not acceptable as scuba stations, per DSB recommendations. In December 1986, surface sampling was conducted at 11 of these beds. The following data were collected: (i) A vegetation sampler was used to collect a sample of eelgrass from each transect; and (ii) one blade was picked randomly from each vegetation sample for length and width measurements. Length measurements were taken from eelgrass blades with rhizomes attached; it was often difficult to collect entire blades because they would break off before the rhizome pulled free of the substrate. The eelgrass blade length and width were substituted into

the multiple regression equation. Results were then averaged to determine eelgrass density.

RESULTS

Distribution and Eelgrass Bed Area

There are 37 known eelgrass beds in Tomales Bay (Figure 1) with a total area of 3.9 million m^2 as measured in March 1987 (Table 2). The larger beds between Walker Creek and Tom's Point remain stable in area from year to year, while smaller eelgrass beds may disappear entirely one year then reappear the next year (Spratt 1986, 1987). Consequently there is very little annual variation in the total area of eelgrass in Tomales Bay. Eelgrass bed measurements are revised seasonally in conjunction with herring spawning-ground surveys conducted by the author. These data are available on request.

TABLE 2: Eelgrass Bed Measurements, March 1987, Tomales Bay, California.

Bed number*	*Area m^2*	*Bed* number*	*Area m^2*
1	4,400	12	1,800
1A	33,000	13	100
1B	21,000	14	1,000
1C	1,500	15	100
2	2,800	16	42,000
2A	2,000	16A	14,600
3	3,800	17	2,200
3A	0	18	0
4	1,000	19	116,600
5	12,000	20	235,500
6	7,400	20A	55,900
7	6,000	21	1,488,000
8	9,100	22	140,000
9 North	13,900	23	1,209,000
9 South	21,000	24	20,900
10	4,100	25	200,000
11 North	17,400	26	190,000
11 Middle	5,000	27	21,000
11 South	1,600	28	0
		28A	11,800

Total area 3,915,700 m^2

* See Figure 1.

Hardwick (1973) estimated that over 90% of the eelgrass in Tomales Bay is found at a depth of less than 1.8 m (6 ft) below mean lower low water. My results were similar; however, I found that the maximum depth of eelgrass distribution was 3.6 m (12 ft) below mean lower low water (Figure 1).

Eelgrass Density By Scuba

Wet weight per m^2 of eelgrass is required to compute herring biomass from spawning-ground surveys. The wet weight of eelgrass collected by scuba ranged from 0.2 to 2.7 kg/m^2 (Table 2). Results compared favorably with 1976 eelgrass density estimates from scuba samples which ranged from 0.4 to 1.9 kg/m^2 (Spratt 1976). Hardwick (1973) found average eelgrass density of 1.6 kg/m^2 in Tomales Bay. Winter estimates of eelgrass density in Humboldt Bay, another northern California embayment, ranged from 0.3 to 2.1 kg/m^2 (Harding and Butler 1979).

Eelgrass Blade Measurements

Eelgrass blade length and width data were measured from scuba samples (Table 1) and from surface samples (Table 3). Differences in results between the two methods reflected different sampling areas. The deep beds sampled from the surface tended to be more lush than shallower beds samples with scuba. Average blade length ranged from 0.5 to 1.3 m (Table 3). Average blade width ranged from 7 mm (Table 1) to 14 mm (Table 3).

TABLE 3. Measurements of Eelgrass from the Surface and Estimate of Eelgrass Density from Regression.

Bed no.	*Transect no.*	*Blade length m*	*Blade width mm*	*Kg/m^2 from regression*	*Average density*
10	1	.87	9	1.4	
	2	1.71	12	3.5	
	3	1.34	13	2.7	2.53
11	1	1.42	9	2.6	
	2	1.08	11	2.0	
	3	1.13	11	2.2	2.26
12	1	1.48	10	2.9	
	2	1.08	10	2.0	
	3	.63	11	1.1	2.0
14	1	.92	11	1.7	
	2	.73	11	1.3	
	3	.84	11	1.6	1.53
16	1	.65	10	1.1	
	2	1.35	12	2.7	
	3	.81	11	1.4	1.73
16A	1	1.22	16	2.8	
	2	.80	13	1.6	
	3	.95	14	2.0	1.80
20	1	.61	10	0.9	
	2	.54	6	.5	
	3	.47	9	0.6	0.67
21	1	1.10	10	2.0	
	2	1.55	9	2.9	
	3	1.13	10	2.1	2.33
22	1	.90	11	1.7	
	2	1.49	9	2.8	
	3	.70	10	1.1	1.86
23	1	.51	8	0.6	
	2	.81	10	1.4	
	3	1.68	10	3.3	1.77
24	1	1.90	11	3.9	
	2	.94	9	1.6	
	3	.62	8	0.8	2.10

Note: Beds 1B, 1C, 2A, 3A, 19 and 20A were not sampled. Beds 13, 15, 17, and 18 could not be found.

Percent Bottom Covered By Eelgrass

Most eelgrass beds were either uniformly dense with nearly 100% bottom coverage (Figure 2A) or scattered with 70–90% bottom cover (Figure 2B). The percent of the bottom with plant growth was above 90% in 18 beds and below 73% in only 1 bed (Table 1 and 3). Individual blades or blade bundles could not be counted acoustically due to dense distribution of the eelgrass and poor resolution of fathometer recordings.

Percent bottom cover was not a good measure of density. Very light to extremely dense beds may all have 100% bottom cover. A high resolution fathometer in conjunction with a color monitor may give results that are better correlated with density.

Eelgrass Density Estimates By Regression

The best relationship was obtained by the multiple regression of blade length (in meters) and width (in millimeters) on weight per unit area (kg/m^2):

$$\text{density} = .002177\ (L) + .0765\ (W) - 1.1801,\ r = .78.$$

The density of eelgrass beds was calculated by substituting blade length and width from Table 3 in the regression equation. An independent estimate was made for each transect. The density of eelgrass in each bed was the mean of the estimates for transects within that bed. Using bed 11 as an example:

$$\text{density} = .002177\ (L) + .0765\ (W) - 1.1801$$

substituting transect 1 values

$$= .002177(1425) + .0765(9) - 1.1801$$

$$= 2.6\ kg/m^2$$

The average density of bed 11 computed from the three transects was 2.2 kg/m^2.

Estimates of average eelgrass density from regression calculations ranged from 0.7 to 2.5 kg/m^2 (Table 3).

Peak Eelgrass Density

Eelgrass density estimates in this report are from Tomales Bay during winter. Density of eelgrass peaks sometime during the summer growing season. Harding and Butler (1979) estimated that summer eelgrass density in Humboldt Bay, California ranged from 4.7 to 6.9 kg/m^2. Similar peak densities may be expected for Tomales Bay.

CONCLUSION

Eelgrass distribution is relatively stable from year to year in Tomales Bay. However, density is highly variable within and between beds seasonally and probably changes from year to year. Therefore, because eelgrass density is required to calculate herring biomass estimates, real time estimates are needed.

The multiple regression model provides one means of estimating eelgrass density. The coefficient of determination ($r^2 = 0.61$) between eelgrass measurements and density estimates from scuba sampling indicates that only 61% of the variation in eelgrass density was attributable to eelgrass measurements. Large natural variation was found in eelgrass parameters measured. Increasing the number of blades measured per quadrat and including an improved acoustical variable may improve the regression.

The regression should be used with caution. However, it is suited to areas where rapid eelgrass density estimates are needed and neither scuba divers nor other means of directly measuring eelgrass density are available.

ACKNOWLEDGMENTS

This research could not have been accomplished without the cooperation of the California Department of Fish and Game Diving Safety Board, particularly Jack Ames and Fred Wendell who volunteered to dive in Tomales Bay. Phil Law of the Department's statistical unit at Menlo Park provided a great deal of assistance in data analysis. I also extend a grateful thank you to Margaret Graham and Kate Symonds for collecting and measuring eelgrass from Tomales Bay, and to Sandy Wyllie Echeverria for piquing my curiosity about eelgrass.

LITERATURE CITED

Deatwyler, Calvin C. 1966. Marine geology of Tomales Bay, central California. U. of Pacific, Pac. Mar. Sta. Res. Rep. (6):1–169.

Harding, Lawrence W. and James H. Butler. 1979. The standing stock and production of eelgrass, *Zostera marina,* in Humboldt Bay, California. Calif. Fish and Game, 65(3):151–158.

Hardwick, James E. 1973. Biomass estimates of spawning herring, *Clupea harengus pallasi,* herring eggs, and associated vegetation in Tomales Bay. Calif. Fish and Game, 59(1):36–61.

Maceina, Michael J., J. V. Shireman, K. A. Langeland, and D. E. Canfield. 1984. Prediction of submersed plant biomass by use of a recording fathometer. J. Aquatic Plant Mgt., 22:35–38.

Spratt, J. D. 1976. The Pacific herring resource of Tomales and San Francisco Bays: its size and structure. Calif. Fish and Game, Mar. Res. Tech. Rep. No. 33:1–44.

_____. 1981. Status of Pacific herring, *Clupea harengus pallasi,* resource in California. Calif. Fish and Game, Fish Bull. 171:1–107.

_____. 1986. Biomass estimates of Pacific herring, *Clupea harengus pallasi,* in California from the 1985–86 spawning-ground surveys. Calif. Dept. Fish and Game, Mar. Resources Admin. Rep. No. 86-3:1–28.

_____. 1987. Biomass estimates of Pacific herring, *Clupea harengus pallasi,* in California from the 1986–87 spawning-ground surveys. Calif. Dept. Fish and Game, Mar. Resources Admin. Rep. No. 87-12:1–29.

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OXYGEN AND TEMPERATURE RELATIONSHIPS IN NINE ARTIFICIALLY AERATED CALIFORNIA RESERVOIRS [1]

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Thermal destratification and the ratio of air volume injected (Qa) to reservoir water volume (V) were positively correlated in nine southern California reservoirs. There was no correlation between either Qa/V and minimum oxygen concentrations in these reservoirs, nor between oxygen minima and thermal destratification. Although artificial aeration is usually used to increase oxygen concentrations to a desired level, there are presently no quantitative procedures for sizing a destratification system to achieve the desired oxygen concentrations.

INTRODUCTION

Artificial thermal destratification by air injection is a common reservoir management technique. The principal management objectives include elimination of anaerobic conditions near the reservoir's bottom, creation of additional fish habitat, and improvement in drinking water quality. These objectives, as well as thermal destratification of the reservoir, are sometimes obtained when the rising air bubbles upwell anaerobic bottom waters to the reservoir's surface where the upwelled waters mix with aerobic surface waters. This mixing process continues until either a semi-steady state is achieved without complete thermal destratification or until the reservoir is isothermal (Fast 1968; Fast and St. Amant 1971).

The rationale for aeration by destratification is that either partial or complete thermal destratification will reoxygenate the anaerobic bottom waters by three processes: (i) redistribution of oxygen rich surface waters into the bottom waters by the mixing process, (ii) absorption of oxygen from the injected air by the bottom waters, and (iii) atmospheric oxygen recharge of the upwelled deep water at the lake's surface. Redistribution of oxygen is generally considered the most important of these three processes (Lorenzen and Fast 1977).

Although artificial destratification usually results in the elimination of anaerobic conditions, the relationship between the degree of mixing and the resultant oxygen concentration of deep water has not been evaluated. Intuitively, one might expect the highest oxygen concentrations to occur in those reservoirs with the most thorough water mixing regime. Therefore, our objective was to determine whether or not there is a relationship between degree of mixing and minimum oxygen concentrations in nine southern California reservoirs during artificial destratification.

[1] Accepted for publication July 1989.

METHODS

Nine southern California reservoirs (Table 1) were monitored during August 1979 for dissolved oxygen and water temperature at multiple depths. Casitas Reservoir was also monitored during 1978. August was chosen because each reservoir had at least two months of repeated or continuous aeration and had approached nearly steady state temperature and oxygen conditions.

Table 1. Some Characteristics of Nine Southern California Reservoirs During Artificial Aeration by Air Injection. The Temperature Differences and Minimum Oxygen Concentrations are During August 1979 for Each Reservoir, plus August 1978 for Casitas Reservoir. Data from Fast and Hulquist (1982).

Reservoir	Water volume (V; $10^6 ft^3$)	Air volume (Qa, SCFM)	Qa/V ($\times 10^{-6}$)	Temperature[2] Difference (°C)	Minimum[3] Oxygen (mg/l)
1. Puddingstone	267	240	0.90	0.4	4.0
2. Mathews	6,379	800	0.12	2.6	3.0
3. Perris	3,409	315	0.09	5.5	1.0
4. Skinner	1,822	600	0.33	3.2	0.5
5. Wohlford	235	109	0.46	1.3	1.0
6. El Capitan	2,915	215	0.07	3.9	0.0
7. Murray	180	240	1.33	1.2	5.0
8. Morena	1,240	240	0.19	4.5	0.0
9. Casitas (1978)	10,945	450	0.04	8.4	3.5
9. Casitas (1979)	10,838	615	0.06	8.9	3.5

[1] Mean air injection rate adjusted monthly for hours of operation during the month, in standard cubic feet per minute (SCFM).
[2] Temperature difference between the surface and diffuser depth.
[3] Oxygen concentration at the bottom of mixed volume.

All nine reservoirs were artifically mixed by compressed air injection, but the aeration system design and air input rates varied greatly. Fast and Hulquist (1982) describe each aeration system in detailed and thoroughly discuss monitoring techniques and effects of air injection on nitrogen gas concentrations.

A nonparametric test, the Spearman rank correlation coefficient, (Siegel 1956) was used to compare paired observations of dissolved oxygen, temperature and air injection rates.

RESULTS AND DISCUSSION

The ratio (Qa/V) of air injection rate (Qa) to water volume (V) varied greatly between the nine reservoirs (Table 1). Casitas Reservoir had the lowest ratio (0.04), while Lake Murray had the highest (1.33). Temperature differences between the surface and the air injection depth ranged from 0.4 °C at Puddingstone to 8.9 °C at Casitas. There is a significant negative correlation between temperature differences and the Qa/V ($r_s = -0.89$, $p < 0.01$). The relationship is slightly curvilinear when plotted on a semilog scale (Figure 1). Thus, the degree of mixing was closely related to air input per unit water volume. This relationship is not too surprising, even though the reservoirs varied greatly in physical configuration, aeration system design, and aerator operation (Fast and Hulquist 1982).

Although Qa/V and thermal destratification are well correlated, Qa/V and minimum dissolved oxygen concentrations are not significantly correlated ($r_s = 0.24$, $p > 0.05$). There is no clear relationship between these variables (Figure 2).

Likewise, there is no significant correlation between the thermal destratification and minimum dissolved oxygen concentrations ($r_s = -0.28$, $p > 0.05$). The plot of those paired observations is likewise without obvious pattern (Figure 3).

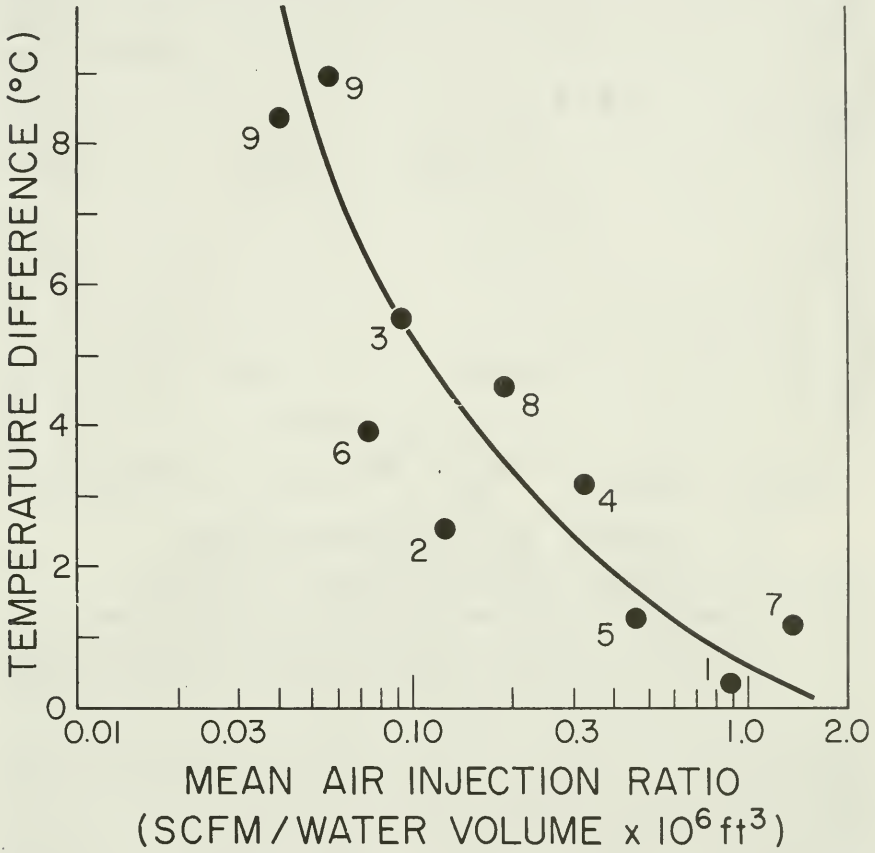

FIGURE 1. The relationship between the mean compressed air injection ratio (Qa; or standard cubic feet per minute, SCFM) to reservoir water volume (V), and the temperature differences between the surface and air injection depth at nine southern California reservoirs during artificial destratification. The regression line is fitted by hand. The data point numbers correspond to reservoir numbers shown in Table 1.

There apparently is no relationship between the degree of artificial mixing and minimum dissolved oxygen concentrations. While this may be true between reservoirs over the Qa/V range that we tested, it is not necessarily true for any given reservoir. The nine reservoirs that we monitored ranged from mesotrophic (e.g. Casitas) to highly eutrophic (e.g. Morena). Without artificial aeration, Casitas might not reach zero dissolved oxygen concentration until October or later; whereas, Morena would reach zero soon after stratification develops, perhaps as early as March. Consequently, while a given Qa/V at the two reservoirs might produce similar temperature conditions, Morena requires a much greater Qa/V than does Casitas to achieve the same minimum dissolved oxygen concentrations.

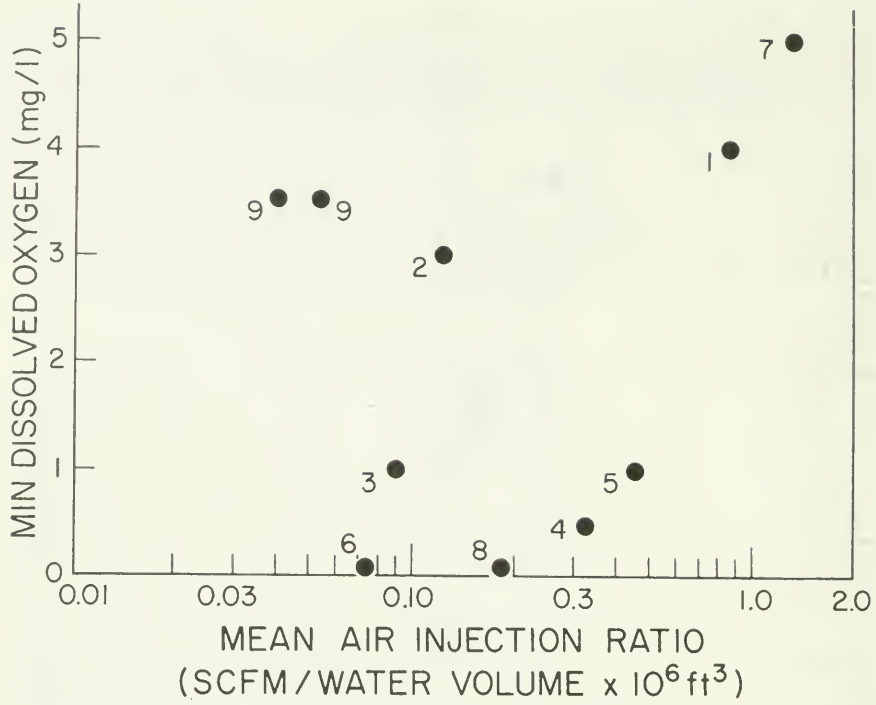

FIGURE 2. The relationship between the mean compressed air injection (Qa; or standard cubic feet per minute, SCFM) to reservoir water volume (V), and minimum dissolved oxygen concentrations above the air injection depth at nine southern California reservoirs during artificial destratification. The data point numbers correspond to reservoir numbers shown in Table 1.

Although taken as a whole, there is no significant relationship between minimum dissolved oxygen and degree of mixing, note that the relationships change if we remove the Casitas Reservoir data from Figures 2 and 3. Consideration of the remaining data points results in significant correlations of $r_s = 0.67$ ($p < 0.05$) and $r_s = -0.73$ ($p < 0.05$) respectively. Although these relationships are improved, there is still substantial scatter, including too much for predictive purposes. Air injection rate and degree of thermal destratification appear to be important variables in developing a predictive model for minimum dissolved oxygen, but other variables must be considered as well, such as the trophic state of the reservoir.

In most cases, thermal destratification is less important than attaining a higher minimum dissolved oxygen concentration. Dissolved oxygen minima greater than 1.0 mg/l are usually sufficient for most domestic water quality purposes. However, dissolved oxygen concentrations for fish must be greater. Miller and Fast (1981) found at El Capitan Reservoir that many warm water fish would not utilize water volumes that had less than 3 mg/l dissolved oxygen, even though the reservoir was well mixed thermally. Consequently, it is necessary to design a destratification system for a given reservoir to meet a specific objective, whether it be for domestic use or fish survival.

There are presently no quantitative procedures for designing a reservoir aeration system to achieve a desired minimum dissolved oxygen concentration;

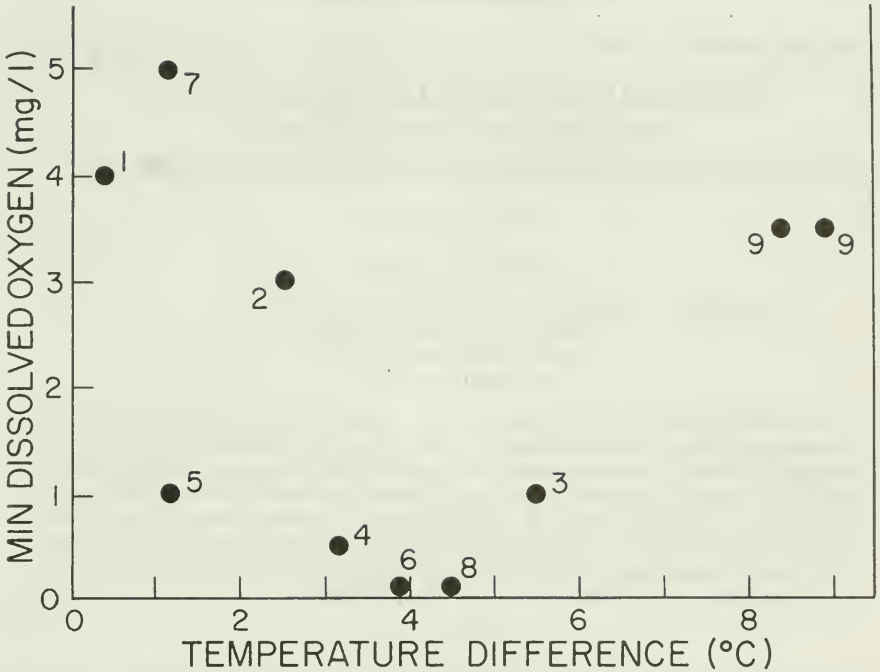

FIGURE 3. The relationship between the temperature differences between the surface and air injection depth, and minimum dissolved oxygen concentrations at the air injection depth at nine southern California reservoirs during artificial destratification. The data point numbers correspond to reservoir numbers shown in Table 1.

although Lorenzen and Fast (1977) describe a procedure for achieving a given level of thermal destratification. Likewise, Figure 1 of this paper can also be used for that purpose. Neither method, however, can be used to predict minimum dissolved oxygen concentrations. Practitioners, with extensive experience with reservoirs aeration systems, and with adequate background information on a given reservoir, might be able to design an aeration system that will achieve a minimum dissolved oxygen concentration. Clearly, an objective, quantitative procedure is needed for designing aeration systems to meet minimum oxygen needs in reservoirs, especially for the average potential user.

LITERATURE CITED

Fast, A. W. 1968. Artificial destratification of El Capitan Reservoir by aeration, part I, effects on the chemical and physical parameters. Calif. Dept. Fish and Game, Fish Bull. 141, 97 p.

Fast, A. W. and R.G. Hulquist. 1982. Supersaturation of nitrogen gas caused by artificial aeration in reservoirs. U.S. Army Corps of Engineers, Tech. Rept. E-82-9; National Tech. Information Service, Springfield, VA.

Fast, A. W., and J. A. St. Amant. 1971. Nighttime artificial aeration of Puddingstone Reservoir, Los Angeles County, California. Calif. Fish and Game, 57(3):213–216.

Lorenzen, M.W. and A.W. Fast. 1977. A guide to aeration/circulation techniques for lake management. U.S. Environmental Protection Agency. Ecological Research Series. EPA-600/3-77-004, Jan. 125 p.

Miller, L.W., and A.W. Fast. 1981. The effects of artificial destratification on fish depth distribution in El Capitan Reservoir, California. in: F.L. Burns and I.J. Powling, eds., Destratification of lakes and reservoirs to improve water quality. Australian Government Publishing Service, Canberra, p. 498–514.

Siegel, S. 1956. Nonparametric statistics for the behavioral sciences. McGraw-Hill Book Co., New York. 312 p.

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TEMPORAL AND SPATIAL VARIATION IN PELAGIC FISH ABUNDANCE IN LAKE MEAD DETERMINED FROM ECHOGRAMS [1]

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We scored echograms on a scale of 1 to 5 and used these scores as relative estimates of pelagic fish abundance in Lake Mead, Arizona-Nevada. Spatial and temporal patterns in fish abundance and the association between fish abundance and chlorophyll *a* concentration were tested with nonparametric statistical methods. We found no difference in fish abundance between years of our study ($p = 0.5017$), but there was significant seasonal ($p = 0.0068$) and spatial ($p < 0.0001$) heterogeneity in abundance. Fish abundance was positively correlated with chlorophyll *a* concentration ($r_s = 0.533$, $p < 0.0001$).

INTRODUCTION

Echograms have been used extensively to locate and estimate the relative abundance of marine fish stocks (Cushing 1973). In freshwater, echograms have been used to describe vertical (Netsch et al. 1971; Eggers 1978; O'Brien et al. 1984; Matthews et al. 1985), spatial (O'Brien et al. 1984; Wanjala et al. 1986) and temporal (Baker and Paulson 1983) patterns in fish abundance. Although most uses of echograms have been qualitative, Mullan and Applegate (1969) and Matthews et al. (1985) obtained relative estimates of fish abundance by counting targets (fish) on echograms. However, neither Mullan and Applegate (1969) nor Matthews et al. (1985) presented any statistical analysis of estimates obtained from echograms. Our purposes in this paper are to: 1) describe a procedure we have used for the scoring and statistical analysis of echograms as relative estimates of pelagic fish abundance; and 2) describe temporal and spatial variation in pelagic fish abundance in Lake Mead.

METHODS

As part of a limnological survey of Lake Mead, a large mainstem impoundment of the Colorado River, Arizona-Nevada, we conducted monthly echosounding surveys from March 1981 through December 1982. On each sampling date we echosounded transects, approximately 1km in length, with a Furuno Model FM 22-A recording echosounder. The echosounder has a beam angle of 28° and an operating frequency of 50 KHz; maximum and effective paper widths are 150 and 130 mm, respectively, and paper feeds at a rate of 10 mm/ min. We operated the echosounder with the depth range set at 100 or 50 m and gain (sensitivity) generally set at 4 (on a scale of 0 to 10). Transects were run

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between 0800 and 1300 hrs at a speed of 8 km/ h in the immediate vicinity of each of 13 sampling stations (Figure 1).

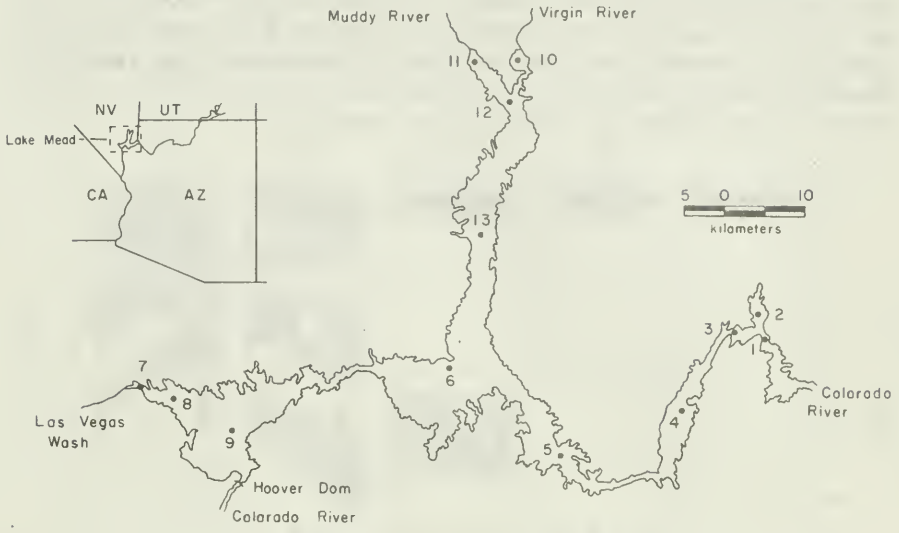

FIGURE 1. Lake Mead, Arizona-Nevada, with echosounding stations indicated by solid circles.

After all field work was completed, we assembled and ranked, 1 through 5, a reference set of echograms (Figure 2) that encompassed the range in target number and density observed in our sample echograms. Each sample echogram was compared with the reference series and scored 1 to 5. Changes in depth range affect the apparent number and density of targets in echograms; therefore, we also referred to a series of echograms in which depth range was alternately set at 50 and 100 m. To ensure consistency, all sample echograms were evaluated and scored in a single session by one person (GRW).

We used these scores as estimates of the relative abundance of pelagic fish in Lake Mead. To test differences in fish abundance between years we used a Mann-Whitney U-test; differences in fish abundance between seasons (winter= December through February; spring= March through May; summer= June through September; fall= October and November) and between sampling stations were tested with a Kruskal-Wallis one-way analysis of variance. We used Spearmans rank correlation (r_s) to test the association between fish abundance and chlorophyll *a* concentration; chlorophyll *a* data were obtained from Paulson and Baker (1983).

RESULTS AND DISCUSSION

Only in exceptional situations (e.g., Wanjala et al. 1986) is it possible to identify individual species in echograms. However, electrofishing, fish trapping and midwater trawls (Deacon et al. 1972; Paulson and Espinosa 1975; Allan and Roden 1978) have shown that pelagic fish populations in Lake Mead are almost exclusively composed of threadfin shad, *Dorosoma petenense*. Also, a concurrent series of meter-net tows and echogram transects made at seven locations

in Lake Mead on 21 June 1987 showed that estimates of pelagic fish abundance obtained from echograms were highly correlated ($r_s = 0.847$, $p = 0.0162$) with meter-net catches composed entirely of threadfin shad. Estimates of fish abundance derived from echograms appear to be specific for threadfin shad in Lake Mead; however, we refer to these as estimates of total pelagic-fish abundance because large fish (e.g., striped bass, *Morone saxatilis*, and carp, *Cyprinus carpio*) frequently occur in our echograms.

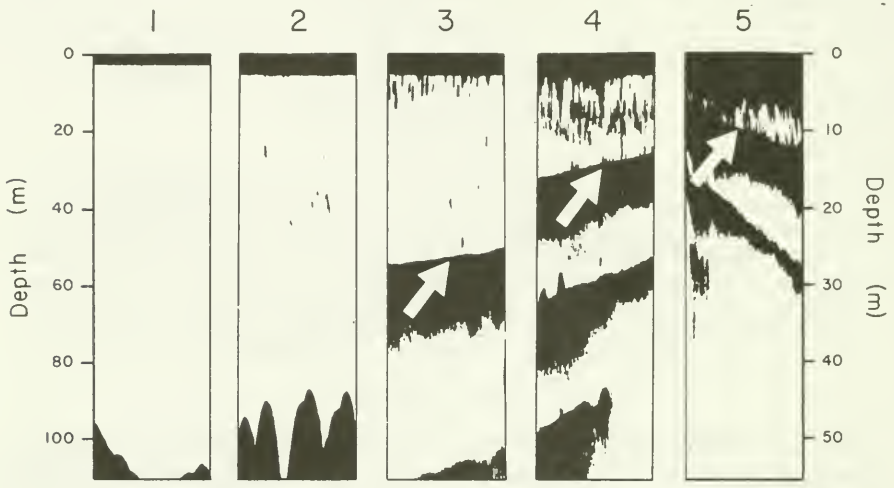

FIGURE 2. Reference series of echograms. Numbers indicate relative abundance of pelagic fish: 1- no targets (fish) present; 2- few; 3- several; 4- abundant; 5- dense, over-lapping targets. Arrows indicate lake bottom. Echograms 1–4 are from a transect made between stations 7 and 9 on 6 August 1982; echogram 5 was made at station 9 on 13 July 1982. Depth-range setting was 0–100 m for echogram 1 and 0–50 m for echograms 2–5.

Pelagic fish abundance exhibited considerable temporal and spatial variation in Lake Mead during 1981 and 1982 (Table 1). There was no difference in abundance between years ($p = 0.5017$) so data were pooled. Seasonal variation in fish abundance was highly significant ($p = 0.0068$). Fish abundance was greatest in the summer, following the threadfin shad spawn in May–June; abundance declined during fall and winter, but there was no change from winter to spring. Seasonal abundance of threadfin shad in Lake Mead shows a similar pattern based upon electrofishing results (Deacon et al. 1972) and occurrence in stomachs of striped bass (Wilde and Paulson 1989).

There was a highly significant spatial variation in fish abundance ($p < 0.0001$) that was not attributable to variation in water temperature, dissolved oxygen concentration, pH and conductivity (Wilde 1984). Fish abundance was greatest near the inflows of the Colorado (Stations 1–3), Virgin (Station 10) and Muddy (Station 11) rivers and the Las Vegas Wash (Station 7) and decreased downstream from these inflows. Chlorophyll *a* concentration, a measure of phytoplankton abundance, exhibited a similar distribution (Wilde 1984) and was positively correlated with fish abundance ($r_s = 0.533$, $p < 0.0001$). This correlation is based upon 256 station-date observations and is a measure of both the seasonal and spatial association between chlorophyll *a* and fish abundance.

Table 1. Relative Abundance of Pelagic Fish in Lake Mead, 1981–1982, determined from Echograms. Station Numbers are as in Figure 1.

Date	Station 1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
March 19–21, 1981	2	3	2	1	1	1	3	2	1	5	2	2	NS[1]	2.1
April 14–16	4	2	3	3	1	1	4	3	1	5	3	3	1	2.6
May 13–15	3	2	3	1	1	1	3	2	1	1	1	1	1	1.6
June 22–24	2	3	4	2	2	1	3	3	1	4	2	2	1	2.3
July 21–23	2	2	2	1	1	1	4	3	1	3	3	2	1	2.0
August 18–20	3	3	3	1	1	1	3	2	1	2	2	1	1	1.8
September 15–17	2	2	2	1	1	1	2	2	1	2	2	1	1	1.5
October 19–21	2	2	2	1	1	1	3	2	1	2	2	1	1	1.6
November 23–27	2	1	1	1	1	1	2	1	1	2	2	2	1	1.4
December	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
January 18–22, 1982	2	2	2	1	1	1	4	2	1	2	2	2	2	1.8
February 17–19	2	2	2	1	1	2	2	1	1	2	2	1	1	1.5
March 23–25	2	1	2	1	1	1	2	2	1	2	2	1	1	1.5
April 20–23	3	3	3	2	2	1	3	2	2	3	2	2	1	2.2
May 10–12	2	2	2	1	1	1	2	2	1	2	1	1	1	1.5
June 20–24	2	2	2	2	1	2	4	3	2	4	2	2	1	2.2
July 13–15	3	2	3	1	2	2	5	2	2	4	2	2	1	2.4
August 10–12	3	2	4	1	1	1	5	2	2	3	4	2	2	2.5
September 8–10	2	2	3	2	1	1	3	2	2	2	2	2	1	1.9
October 6–8	2	2	3	1	1	1	4	2	2	3	3	2	1	2.1
November 9–12	2	3	3	1	1	2	3	2	1	2	2	2	1	1.9
December 14–16	2	2	2	1	1	1	4	1	1	2	2	1	1	1.6
Station means	2.3	2.1	2.5	1.3	1.1	1.1	3.2	2.0	1.3	2.7	2.1	1.7	1.1	

[1] NS = not sampled

Annual means (for each station) for fish abundance and chlorophyll *a* (Figure 3) which reflect only spatial trends were highly correlated ($r_s = 0.850$, $p < 0.0001$). Positive relationships between the spatial distributions of threadfin shad and chlorophyll *a* have been reported by Rinne et al. (1982) and Siler et al. (1986).

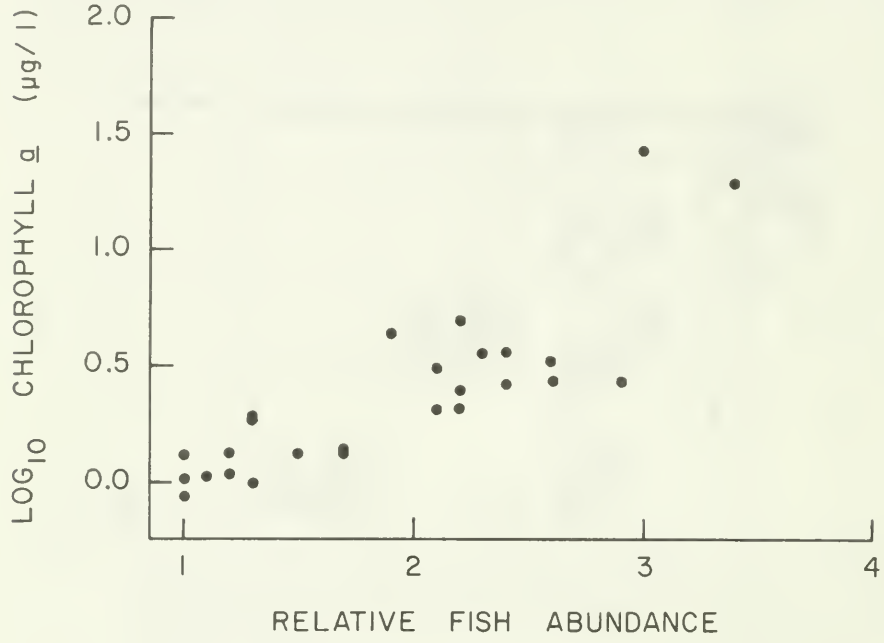

FIGURE 3. Scatterplot of annual means of relative fish abundance and log chlorophyll *a* concentration ($r_s = 0.850$; $p < 0.0001$; $N = 26$). Note, r_s is unaffected by log transformation of chlorophyll *a*.

Mullan and Applegate (1969) suggested that echograms could provide information on temporal, vertical and spatial patterns in fish abundance. Estimates of fish abundance derived from echograms are relative; however, these estimates meet the requirements and assumptions of many commonly used nonparametric methods and can be used to test hypotheses concerning trends in fish abundance. Our scoring scheme is only one of many possible; for example, fewer or more than five ranks could be used. Counts of individual targets or output from an optical digitizer could also be analyzed as relative estimates of fish abundance.

Echosounding requires a minimal investment of manpower and money compared with conventional sampling techniques (gill netting, electrofishing, etc.). More advanced hydroacoustic systems that supply quantitative estimates of fish abundance also require a small investment of manpower; however, such systems are expensive. Thorne (1983) estimated that the minimum cost for a hydroacoustic system with signal integration that produces data of scientific quality was $50,000; recording echosounders can be obtained for as little as 1 to 2% of that amount.

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LITERATURE CITED

Allan, R.C., and D.L. Roden. 1978. Fish of Lake Mead and Lake Mohave. Nev. Dept. of Wildl., Biol. Bull. No. 7. 105 p.

Baker, J.R., and L.J. Paulson. 1983. The effects of limited food availability on the striped bass fishery in Lake Mead. Pages 551–561 *in* V.D. Adams and V.A. Lamarra, eds. Aquatic resources management of the Colorado River ecosystem. Ann Arbor Science Publications, Inc., Ann Arbor.

Cushing, D.H. 1973. The detection of fish. Pergammon Press Inc., Elmsford.

Deacon, J.E., L.J. Paulson, and C.O. Minckley. 1972. Effects of Las Vegas Wash effluents upon bass and other game fish reproduction and success. Final report, Dingell Johnson Project, Nevada F20. Univ. Nev., Las Vegas. 68 p.

Eggers, D.M. 1978. Limnetic feeding behavior of juvenile sockeye salmon in Lake Washington and predator avoidance. Limnol. Oceanogr., 23:1114–1125.

Matthews, W.J., L.G. Hill, and S.M. Schnellhaas. 1985. Depth distribution of striped bass and other game fish in Lake Texoma (Oklahoma-Texas) during summer stratification. Amer. Fish. Soc., Trans., 114:84–91.

Mullan, J.W., and R.L. Applegate. 1969. Use of an echosounder in measuring distribution of reservoir fishes. U.S. Bur. Sport Fish. Wildl. Tech. Pap. No. 19. 16 p.

Netsch, N.F., G.M., Kersh, Jr., A. Houser, and R.V. Kilambi. 1971. Distribution of young gizzard and threadfin shad in Beaver Reservoir. Pages 95–105 *in* G.E. Hall, ed. Reservoir fisheries and limnology. Spec. Publ. 8, American Fisheries Society, Bethesda, MD.

O'Brien, W.J., B. Loveless, and D. Wright. 1984. Feeding ecology of young white crappie in a Kansas reservoir. No. Amer. J. Fish. Mgmt., 4:341–349.

Paulson, L.J., and J.R. Baker. 1983. Limnology of reservoirs in the Colorado River. Lake Mead Limnol. Res. Center, Univ. Nevada, Las Vegas. Tech. Rept. No. 11. 276 p.

Paulson, L.J., and F.A. Espinosa. 1975. Fish trapping: a new method of evaluating fish species composition in limnetic areas of reservoirs. Calif. Fish and Game, 61:209–214.

Rinne, J.N., W.L. Minckley, and P.O. Bersell. 1982. Factors influencing fish distribution in two desert reservoirs, Central Arizona. Hydrobiologia, 80:31–42.

Siler, J.R., W.J. Foris, and M.C. McInerny. 1986. Spatial heterogeneity in fish parameters within a reservoir. Pages 122–136 *in* G.E. Hall and M.J. Van Den Avyle, eds. Reservoir fisheries management: strategies for the 80's. Southern Division American Fisheries Society, Bethesda, MD.

Thorne, R.E. 1983. Hydroacoustics. Pages 239–259 *in:* L.A. Nielsen and D.L. Johnson, eds. Fisheries techniques. American Fisheries Society, Bethesda, MD.

Wanjala, B.S., J.C. Tash, W.J. Matter, and C.D. Ziebell. 1986. Food and habitat use by different sizes of largemouth bass *(Micropterus salmoides)* in Alamo Lake, Arizona. J. Fresh. Ecol., 3:359–370.

Wilde, G.R. 1984. Seasonal and spatial heterogeneity in the limnetic zooplankton community of Lake Mead. MS Thesis, Univ. Nevada, Las Vegas.

Wilde, G.R., and L.J. Paulson. 1989. Food habits of subadult striped bass in Lake Mead, Arizona-Nevada. Southwest. Nat., 34:118–123.

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POPULATION DYNAMICS OF HARBOR SEALS IN THE GULF OF THE FARALLONES, CALIFORNIA [1]

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We surveyed harbor seals, *Phoca vitulina,* in the Gulf of the Farallones, California, at all known haul-out sites from March 1982 through February 1984, and studied them intensively at two haul-out sites, Double Point and the South Farallon Islands, from 1976 to 1986. Though present year round, seals were most abundant onshore during the breeding/molt season (March–July). The relative abundance of seals onshore at Double Point during the 1987 breeding season was double the number in 1976, and at the South Farallon Islands, numbers in 1986 were four times higher than in 1974. Individual females observed at Double Point during two 3-year sets had a 0.89 and 0.92 probability of parturition in successive years.

INTRODUCTION

Harbor seals, *Phoca vitulina,* have occurred in central California throughout historical times (Scammon 1968), but only in the past 20 years have state-wide surveys of their distribution and abundance been conducted (Carlisle and Aplin 1966 and 1971, Frey and Aplin 1970). Aerial surveys between 1983 and 1986 revealed that about 20% of the state population, excluding animals on the southern California Channel Islands, occurs at sites in the Gulf of the Farallones (Hanan, Calif. Dep. Fish and Game, La Jolla, Calif., pers. comm.). Few data, however, have heretofore been reported on population trends and reproductive rates for harbor seals in this region (Ainley, Huber, Henderson, and Lewis 1977, Allen, Ainley, Page, and Ribic 1985). Here we summarize observations of seals at haul-out sites in the Gulf of the Farallones between 1974 and 1987 and present data on reproductive success.

STUDY AREA AND METHODS

The Gulf of the Farallones is bordered by the central California coast from Bodega Bay (lat 38° 20'N) southward to Point Diablo (lat 37° 39'N), and west to the Farallon Islands, 36 km offshore (lat 37° 41'N; Figure 1). Included in our study area are the coastal embayments Tomales Bay, Drakes Estero, and Bolinas

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Lagoon. Much of the coastline, except for that south of the Golden Gate, is largely undeveloped and all is under the jurisdiction of either the Point Reyes National Seashore, U.S. Fish and Wildlife Service, Gulf of the Farallones National Marine Sanctuary, or Golden Gate National Recreation Area.

FIGURE 1. Harbor seal haul-out sites in the Gulf of the Farallones.

In the study area seals haul-out on a diversity of habitats—tidal mud flats, offshore intertidal ledges, and sandy beaches. Coastal haul-out locations include Tomales Point, Point Reyes Headland, Double Point, Duxbury Reef, Tomales Bay, Drakes Estero, and Bolinas Lagoon. The South Farallon Islands (SFI), including Southeast Farallon Island and West End Island, are the only offshore sites, and seals haul-out there primarily on rocky intertidal ledges (Figure 1). Seals do not haul-out on coastal beaches that are heavily used by people south of Bolinas Lagoon.

We counted harbor seals at the Point Reyes coastal sites two times per month from March 1982 through February 1984. Multiple observers surveyed all sites on the same day within a 2-hr period; to obtain maximum numbers on shore, we counted seals when low to medium-low tides occurred between 1200 and 1600 h (e.g., Ainley *et al.* 1977, Allen *et al.* 1985, Fancher 1979, Stewart 1984).

At Double Point, we observed seals on 360 days from January 1976 to June 1987; most counts were made during the breeding season between 1200 and

1600 h at low to medium tide levels. On SFI, counts were made at low tide almost daily to derive a maximum weekly estimate beginning in 1974.

For analysis of seasonal use patterns, we divided the year into the period of breeding and molt (March through July), and the non-breeding period (August through February). Breeding and molt overlap and thus we combined them into one period. We used a two sample t-test on the natural logarithm of the counts to test the null hypothesis that counts of seals ashore did not differ between periods within a year.

We distinguished between adults and pups based on size and coloration. Pups were easily identified during the breeding season at all locations because of their small size and bright silver to black pelage at a time when adults and immatures were a faded, brown color. By the end of June, immature seals began molting and we were no longer able to distinguish pups from immature seals. We, therefore, only counted pups from March through June. Pup numbers were expressed as a percentage of the total number of seals counted. Maximum counts of pups for the region were based on same-day counts at all pupping sites.

We examined the change in relative abundance by regressing the natural logarithm of the mean number of adults and immatures against year for Double Point and for the SFI using SPSSPC+ (Norusis 1986). Parallel slopes for the two sites were tested at alpha = 0.05 using the procedure in Weisberg (1980). The mean number of seals was calculated from the breeding period counts when the maximum number of seals was present.

We were able to identify 23 females at Double Point by shark scars and unusual spot patterns. Healed shark scars are prominent natural markings, and from photographic records and drawings, we were able to reidentify individuals over time.

Following Siniff, DeMaster, and Hofman (1977), the conditional frequency of parturition *(Fp)* of females was determined for successive samples of known females in 3-year sets using the formula:

$$Fp = \frac{N_{i+1}}{N_i}$$

N_1 is the number of known females seen with a pup in $year_1$. Sixteen individual adult females identified from 1977 through 1979 represented set 1, and eighteen individuals from 1982 through 1984 represented set 2. We eliminated from our tabulations two groups of known females: 1) females not seen all three years (see Siniff *et al.* 1977); and 2) those that did not have pups in year 1. Females eliminated in group one may have pupped elsewhere during the year absent, and those in group two may not have been sexually mature in year 1 since size alone is an unreliable measure of age class (McLaren and Smith 1985). The resulting sample sizes were 13 for set 1 and 11 for set 2. The probability of parturition was estimated from a binomial birth model (Siniff *et al.* 1977) with the equation

$$Xp = \frac{\sum P_i}{n},$$

where P is years with pup for female $_i$ divided by total years female $_i$ was present, n is the number of known females, and Xp is the probability of parturition. Only known females present in three successive years were included. If a female was determined to be pregnant because of the size and shape of her abdomen but was not seen attending a pup later, she was included in the sample as having given birth.

RESULTS

Seasonal Use Patterns

Between 1982 and 1984 harbor seals were present throughout the year at coastal locations but their relative abundance ashore varied seasonally with more seals hauled out during the breeding/molt period than during the nonbreeding period (Table 1, 1982: $t = 5.4$, $df = 22$, $p < 0.001$; 1983: $t = 5.82$, $df = 25$, $p < 0.001$). Maximum counts for the coastal region occurred from May through July with 2,502 seals in June 1982 and 2,449 in May 1983. Pups were recorded at all coastal locations and were first observed in late March and last observed in late June. Pup numbers peaked during the first week of May, with 566 in 1982 and 527 in 1983 (Table 2). Pups represented 24% of all seals counted (2,339) in 1982 and 22% of those counted (2,449) in 1983.

Table 1. The average number of seals at sites in the Gulf of the Farallones, by season in 1982–83 and 1983–84. [1]

Year	*Coastal Sites* [2]	*South Farallon Islands*
1982–83		
Breeding/molt		
$\bar{x}$	1841.3	54.8
SE	131.1	2.3
range	1214–2502	36–78
n	11	24
Nonbreeding		
$\bar{x}$	928.3	42.4
SE	91.0	2.2
range	501–1559	20–63
n	13	29
1983–84		
Breeding/molt		
$\bar{x}$	1740.4	53.9
SE	115.8	4.2
range	1242–2449	13–90
n	11	21
Nonbreeding		
$\bar{x}$	997.3	51.6
SE	115.8	4.2
range	621–1591	33–76
n	16	25

[1] $\bar{x}$ is the mean number of seals, SE is the standard error of the sample, and n is the sample size.
[2] Simultaneous counts conducted at all sites except South Farallon Islands.

In contrast to the Point Reyes coastal locations, seasonal variation was seen at SFI in 1982 but not in 1983 (Table 1, 1982: $t = 4.72$, $df = 53$, $p < 0.001$; 1983: $t = 0.5$, $df = 45$, $p = 0.6$). No pups were observed on SFI during the 1982 or 1983 breeding season.

Table 2. Maximum number of pups counted in May (1982 and 1983) in the Gulf of the Farallones for each location; percentage is of the total pup count.

	LOCATION								
	Tomales Bay	*Tomales Point*	*Point Reyes*	*Drakes Estero*	*Double Point*	*Duxbury Reef*	*Bolinas Lagoon*	*South Farallons*	*Total*
1982									
Total	58	135	19	170	263	1	17	0	566
Percentage	10.3	23.9	3.4	30.0	46.5	0.2	3.0		
1983									
Total	45	122	0	122	262	3	17	0	527
Percentage	8.5	22.8	0	23.2	49.7	0.6	3.2		

Double Point

Monthly variation in numbers of seals at Double Point was typical of other coastal sites, with more seals hauled out in the breeding/molt season (Figure 2). Maximum counts occurred in April, May, and June; counts declined from August through November before increasing again in late winter and early spring.

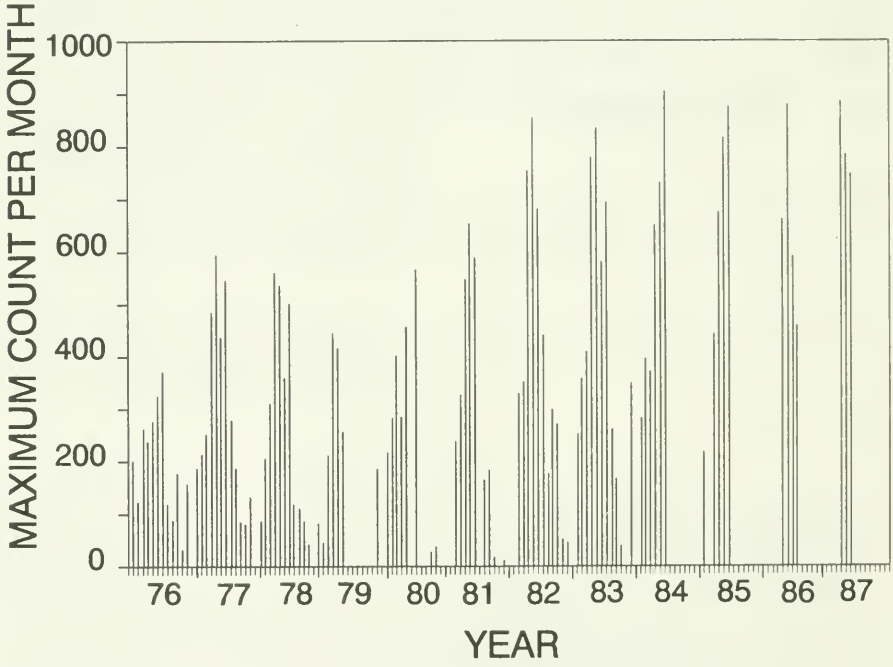

FIGURE 2. Maximum counts of seals onshore at Double Point by month, 1976–87.

Pups were initially seen in late March or early April; maximum pup counts occurred consistently during the first two weeks of May. Nearly half of all pups in the study area occurred at Double Point, 46.5% in 1982 and 49.7% in 1983, the only years when pups were counted at all sites (Table 2). Pups accounted for an average of 32.2% (SE = 0.7, n = 12) of all seals counted at Double Point during the breeding season between 1976 and 1987.

Increase in Relative Abundance of Seals

The abundance of seals at both Double Point and SFI during the breeding /molt period increased slowly from 1976 through 1987 (Figure 3). Over the entire time period of study, the average number counted at Double Point doubled between 1976 (208) and 1987 (443) and quadrupled at SFI between 1974 (8) and 1986 (37); however, both groups grew at the same rate (Double Point: slope = 0.076, $R^2 = 0.88$, SFI: slope = 0.17, $R^2 = 0.71$; parallel slopes: $F = 7.0$, $df1 = 1$, $df2 = 21$, $p > 0.05$). Despite the overall increase during the breeding season at SFI, only 21 pups were seen there between 1974 and 1987, and only 4 were observed in April or May.

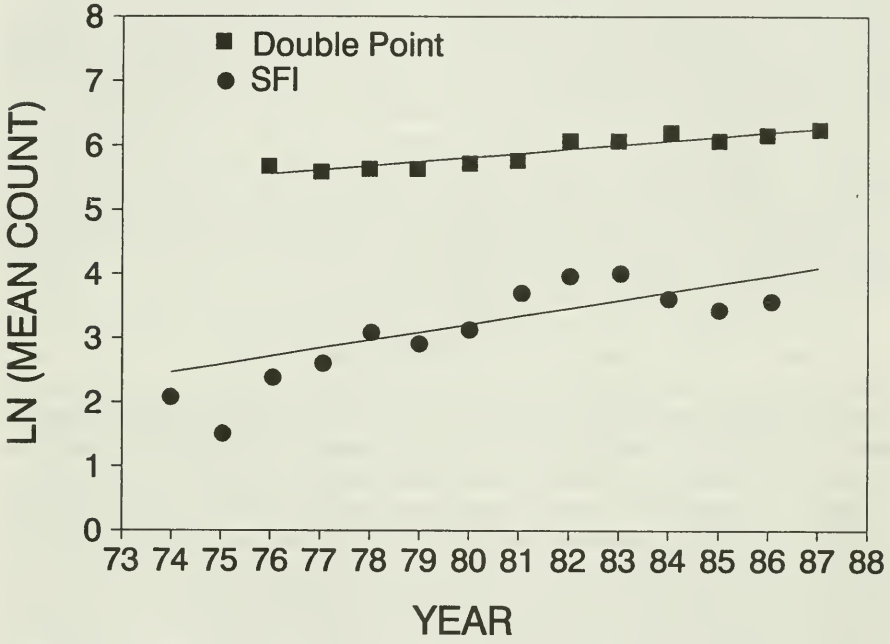

FIGURE 3. Population growth rate of seals at Double Point between 1976 and 1987.

Reproductive Rates

In the first three-year set of data on female pupping at Double Point, a total of 13 females (present all three years) were observed with pups during the first year, 1977. Eleven were observed with pups in the second year, yielding a conditional frequency of parturition of 0.85. The proportion that gave birth all three years for this set was 0.77. In the second set, 11 females (present all three years) were seen with pups in 1982, and all were resighted with pups in 1983. This yielded a conditional frequency of parturition of 1.0; the proportion that gave birth all three years was 0.82. Both sets indicated that once having given birth, a female was very likely to give birth in a successive year. The probability of parturition in any year of the select group returning to Double Point was 0.89 for set 1 and 0.92 for set 2.

DISCUSSION

The relative abundance of harbor seals varied seasonally within the Gulf of the Farallones between 1982–3 and 1983–4 with the exception of SFI in 1983. We suspect that the increase in abundance during the breeding/molt season at Point Reyes coastal locations is related to seals moving from other areas to Point Reyes to breed and to changes in daily haul-out patterns (Allen *et al.* 1985, Stewart 1984, Yochem, Stewart, DeLong, and DeMaster 1987). Seasonal movement was demonstrated by 4 of 17 radio-tagged, adult seals that moved out of the Point Reyes region from Drakes Estero during the fall in 1985 and returned the following breeding season (Miller 1988). Seals may emigrate to Point Reyes from southern San Mateo County haul-out sites from where Slater and Markowitz (1983) believed that adult females departed during the breeding season, a trend also observed at Año Nuevo Island (San Mateo Co.; Le Boeuf and Bonnell 1980). In Oregon, Brown and Mate (1983) speculated that harbor seals moved seasonally between coastal haul-out sites and estuarine ones in response to breeding and feeding preferences, and Roffe and Mate (1984) showed a correlation between harbor seal abundance and migration of salmonid fish in the Rogue River. Congregations of harbor seal nursery herds are also known in other regions (Knudtson 1977, Brown and Mate 1983, Slater and Markowitz 1983). Site fidelity of individual female harbor seals over multiple breeding seasons, though, has not been reported.

The ratio of pups to total animals at Double Point during the breeding season was higher (32.2%) than the 22–24% figures reported for Netarts and Tillamook Bays, Oregon (Brown and Mate 1983), and for sites in British Columbia (20%; Bigg 1969). Our estimates of parturition for females at Double Point may be biased because seals were not randomly selected; however, our figures for the fertility of harbor seals are similar to those of Boulva and McLaren (1979) who calculated a rate for known-age females of 0.79 at age 6, and 0.94 at age 7 and older. Though we were unable to determine the age of our seals, annual rates were similar over the two 3-year sets except for 1984 when the proportion of known females seen with pup declined to 0.61 from a prior average of 0.87 ($SE = 0.01$, $n = 5$). A strong climatic El Nino-Southern Oscillation event may have been a factor in this decline since it appeared to have affected the feeding habits and haul-out patterns of harbor seals in southern California (Yochem 1987, Stewart, Antonelis, DeLong, and Yochem 1988).

Data presented here for Double Point and SFI compared to earlier data (Carlisle and Aplin 1966, 1971) suggest an increase in harbor seal abundance in the Gulf of the Farallones over the past decade. Reproductive success may explain, in part, the increase in relative abundance seen at Double Point; however, the increase at SFI is probably a result of immigration because few pups have been seen there. SFI may be a resting area for migrating, nonbreeding animals; Payne and Schneider (1984) suggested that dispersing juvenile harbor seals accounted for increased abundance at a winter haul-out site in Massachusetts. Stewart *et al.* (1988) also observed a high rate of increase in the number of harbor seals on San Miguel Island, California, between 1973 and 1986 and suggested that immigration was partly responsible.

Changes in mortality rates and in sex and age composition may too have affected the abundance of seals onshore. Seals have been incidentally killed in set gill net fisheries in central California since the early 1980s (P. Wild, Calif. Dep. Fish and Game, Monterey, Calif., pers. commun.); however, the effect of these fisheries on seal population growth rate is uncertain. Changes in age structure could modify seasonal and annual variation in haul-out behavior. In harbor seals, *Phoca vitulina vitulina,* of Orkney, Scotland, Thompson (1987) described sexual and age related differences in molt completion dates and suggested these differences may influence peak abundance onshore for each age class.

The population increase may also be a response to lessened disturbance resulting from expanded public awareness, park/refuge status, and the Marine Mammal Protection Act of 1972 (see also Loughlin 1978), or to a shifting of seals in the region because of habitat loss in San Francisco Bay and at coastal sites in San Mateo County (Bartholomew 1949, Paulbitsky 1975, Slater and Markowitz 1983).

Our results provide information on long-term trends in the relative abundance of seals and indicate that the Gulf of the Farallones, a small region of the state, may support a large concentration of the state's reproductive population. To explain these trends in distribution and abundance or to derive estimates of absolute abundance and of survivorship require additional long-term study involving marked individuals of known age.

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LITERATURE CITED

Ainley, D. G., H. R. Huber, R. P. Henderson, and T. J. Lewis. 1977. Studies on marine mammals at the Farallon Islands, California, 1970–1975. N.T.I.S. No. PB-274-046.

Allen, S. G., D. G. Ainley, G. W. Page and C. A. Ribic. 1985. The effect of disturbance on harbor seal haul out patterns at Bolinas Lagoon, California. Fish. Bull., 82:493–500.

Bartholomew, G. A. 1949. A census of harbor seals in San Francisco Bay. J. Mamm., 30:34–35.

Bigg, M. A. 1969. The harbor seal in British Columbia. Fish. Res. Board Can. Bull., 172:1–33.

Boulva, J., and I. A. McLaren. 1979. Biology of the harbor seal, *Phoca vitulina,* in eastern Canada. Bull. Fish. Res. Bd., Can., 200:1–24.

Brown, R. F., and B. R. Mate. 1983. Abundance, movements, and feeding habits of harbor seals, *Phoca vitulina,* at Netarts and Tillamook Bays, Oregon. U.S. Fish Bull. 81:291–301.

Carlisle, J. G., and J. A. Aplin. 1966. Sea lion census for 1965 including counts of other California pinnipeds. Calif. Fish and Game, 52:119–120.

_____, and J. A. Aplin. 1971. Sea lion census for 1970 including counts of other California pinnipeds. Calif. Fish and Game, 57:124–126.

Fancher L. 1979. The distribution, population dynamics, and behavior of the harbor seal, *Phoca vitulina richardsi,* in south San Francisco Bay, California. Unpubl. M.S. Thesis, Calif. State Univ., Hayward, CA. 109pp.

Frey, H. W., and J. A. Aplin. 1970. Sea lion census for 1969, including counts of other pinnipeds. Calif. Fish and Game, 56:130–133.

Knudtson, P. M. 1977. Observations on the breeding behavior of the harbor seal in Humboldt Bay, California. Calif. Fish and Game, 63:66–70.

Le Boeuf, B. J., and M. L. Bonnell. 1980. Pinnipeds of the California islands; abundance and distribution. Pp. 475–493 in P. M. Power, ed. The California Islands: Proceedings of a multidisciplinary symposium. Haagan Printing, Santa Barbara.

Loughlin, T. R. 1978. Harbor seals in and adjacent to Humboldt Bay, California. Calif. Fish and Game, 64:127–132.

McLaren, I. A., and T. G. Smith. 1985. Population ecology of seals: retrospective and prospective views. Mar. Mamm. Sci. 1:54–83.

Miller, S. A. 1988. [S. G. Allen]. Movement and activity patterns of harbor seals at the Point Reyes Peninsula, California. M.S. Thesis, Univ. of Calif., Berkeley, CA. 70pp.

Norušis, M. J. 1986. SPSS/PC+ for the IBM PC/XT/AT. SPSS Inc., Chicago.

Paulbitski, P. A. 1975. The seals of Strawberry Spit. Pacific Discovery, 28:12–15.

Payne, P. M., and D. C. Schneider. 1984. Yearly changes in abundance of harbor seals, *Phoca vitulina,* at a winter haul-out site in Massachusetts. U. S. Fish Bull., 82:440–442.

Roffe, T. J., and B. R. Mate. 1984. Abundances and feeding habits of pinnipeds in the Rogue River, Oregon. J. Wildl. Manage., 48:1262–1274.

Scammon, C. M. 1968. The marine mammals of the northwestern coast of North America. Dover Publications, New York. 319pp.

Siniff, D. B., D. P. DeMaster, and R. J. Hofman. 1977. An analysis of the dynamics of a Weddell seal population. Ecol. Mono., 47:319–335.

Slater, L. M., and H. Markowitz. 1983. Spring population trends in *Phoca vitulina richardi* in two central California coastal areas. Calif. Fish and Game, 69: 217–226.

Stewart, B. S. 1984. Diurnal hauling patterns of harbor seals at San Miguel Island, California. J. Wildl. Manage., 48:1459–1461.

_____, G. A. Antonelis, Jr., R. L. DeLong, and P. K. Yochem. 1988. Abundance of harbor seals on San Miguel Island, California, 1927 through 1986. Bull. Southern Acad. Sci., 87:39–43.

Thompson, P. M. 1987. The effect of seasonal changes in behavior on the distribution and abundance of common seals, *Phoca vitulina,* in Orkney. Unpubl. Ph.D. Dissert., Univ. of Aberdeen, England. 167pp.

Weisberg, S. 1980. Applied linear regression. Wiley, New York. 283pp.

Yochem, P. K. 1987. Haul-out patterns and site fidelity of harbor seals at San Nicolas and San Miguel Islands, California. M. S. Thesis, San Diego State Univ., San Diego. 89pp.

_____, B. S. Stewart, R. L. DeLong, and D. P. DeMaster. 1987. Diel haul-out patterns and site fidelity of harbor seals (*Phoca vitulina richardsi*) on San Miguel Island, California in Autumn. Mar. Mamm. Sci., 3:323–332.

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BEAVER DISTRIBUTION IN THE TRUCKEE RIVER BASIN, CALIFORNIA [1]

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All beaver, *Castor canadensis*, in the Truckee River Basin appear to have descended from at most nine founding animals. From eight original release sites during 1938–48, beaver had achieved a colony density of 0.72 colonies/km along the Truckee River and 0.20 colonies/km along its tributaries in the summer of 1985. Cottonwood, *Populus trichocarpa*, aspen, *P. tremuloides*, willow, *Salix* spp, and alder, *Alnus incana*, were the most heavily used woody forage species, but all woody species except *Rosa* and *Artemisia* showed at least slight use by beaver.

INTRODUCTION

From 1934 through 1949, the California Department of Fish and Game and the U.S. Forest Service introduced beaver, *Castor canadensis,* into the Sierra Nevada for production of fur, erosion control, and increased water storage (Hensley 1946, Lynn 1949). Two female and three male beaver captured on the Snake River in Bingham and Blaine Counties, Idaho and released on Rowland Creek in Plumas County in 1934 founded the population from which seven of the eight releases into the Truckee Basin were taken (Table 1) (Tappe 1942, Hensley 1946, Lynn 1949). The other release, on the Upper Truckee River in 1938, consisted of four beaver from the Rogue River National Forest, Oregon (Tappe 1942). Except for studies on the beaver population resulting from the 1945 release on Sagehen Creek (Hall 1960, Taylor 1970, Busher 1980), there have been no published reports on the status of introduced beaver in the Sierra Nevada since that of Tappe (1942).

TABLE 1. Beaver Releases in the Truckee River Basin. Map Number Corresponds to Location on Figure 1. Data from Tappe (1942), Hensley (1946) and Lynn (1949). The Animals in the First Release were Trapped in Oregon. All Other Released Beaver Descended from Five Idaho Beaver Transported to Plumas County in 1934. Nevada Wildlife Department did not Release Beaver into the Truckee Basin (W. Mindeville and G. Tanner, pers. comm.). Most of Sierra County (1943 release) lies Outside the Truckee Drainage.

Map			*Number of beaver*			
No.	*Year*	*Location*	*male*	*female*	*sex unknown*	*total*
1	1938	Meiss Meadow, Upper Truckee River	–	–	4	4
–	1943	"Sierra County" site not given in Hensley (1946)	3	2	0	5
2	1945	Sagehen Creek, 6500 ft	2	2	0	4
3	1945	Little Truckee River, 6500 ft	1	1	1	3
4	1945	Martis Creek, 6100 ft	3	2	0	5
5	1945	Juniper Creek, 6200 ft	2	2	0	4
6	1947	Alder Creek, 6550 ft	1	1	0	2
7	1947	Independence Creek, 6950 ft	2	2	0	4
8	1948	Perazzo Creek, 6800 ft	2	2	0	4

[1] Accepted for publication September 1989.

Our objectives were to document the locations of current beaver populations in the Truckee River Basin and to make observations on beaver use of woody forage species.

STUDY AREA

Our study covered the Truckee River and most of its tributaries from the confluence with Deer Creek downstream to Verdi, Nevada. The Truckee River Basin lies within Sierra, Nevada, Placer, and El Dorado counties, California, and Washoe County, Nevada. The dominant vegetation of the area is mixed conifer forest with an overstory of white fir, *Abies concolor*; yellow pine, *Pinus jeffreyi, P. ponderosa, P. washoensis*; and lodgepole pine, *P. contorta*; and a shrub component including greenleaf and whiteleaf manzanita, *Arctostaphylos patula* and *A. viscida*; snowbrush, *Ceanothus velutinus*; squaw carpet, *C. prostratus*; pale serviceberry, *Amelanchier pallida*; rose, *Rosa* spp.; and Sierra gooseberry, *Ribes roezlii*. The mixed conifer forest is replaced in higher elevations by stands of red fir, *Abies magnifica*, western white pine, *P. monticola*, and lodgepole pine; and in lower elevations by open stands of yellow pine and an understory including big sagebrush, *Artemisia tridentata,* antelope bitterbrush, *Purshia tridentata,* and herbaceous plants. Stream banks were characterized by deciduous riparian vegetation consisting of aspen, *Populus tremuloides,* cottonwood, *P. trichocarpa,* willow, *Salix* spp., mountain alder, *Alnus incana,* gray dogwood, *Cornus racemosa,* bitter cherry, *Prunus emarginata,* lodgepole pine, and herbaceous plants.

METHODS

Both banks of each stream were inspected on foot between 5 May and 20 August 1985. Each stream was divided into sampling units approximately 700 m in length. Each stream with perennial water was classified into one of four usage groups: (i) at least one active colony present; (ii) sign of at least one abandoned colony but no active colony; (iii) some past or present beaver usage, but no sign of past or present colony; and (iv) no sign of past or present beaver use. Locations of active and abandoned colonies were mapped on 1:24000 USGS maps. Current and past beaver usage of all woody species was recorded for each stream reach.

RESULTS

Beaver Distribution

Fifty-nine active beaver colonies and 53 abandoned colonies were found in the survey of 214 reaches with perennial water flow, for an average density of 0.38 active colonies per km of stream length (Table 2 and Figure 1). Active colony density on the Truckee River (0.72/km) was higher than on the tributaries (0.20/km). Most colonies were found on low gradient ($< 3\%$) reaches, and nearly 80% of the colonies found on higher gradient streams had been abandoned (Beier and Barrett 1987). Although all release sites were on tributary streams, beaver colonies are now concentrated on the Truckee River. Of the eight known release areas, three sites (Sagehen Creek, Little Truckee River, and Martis Creek) each had several active colonies, and one site (Juniper Creek) no longer had beaver in 1985. The other four sites were not inspected

in 1985. Beaver showed no apparent aversion to human activity, colonizing downtown Truckee and an area adjacent to the U.S. Forest Service's Granite Flat campground on the Truckee River.

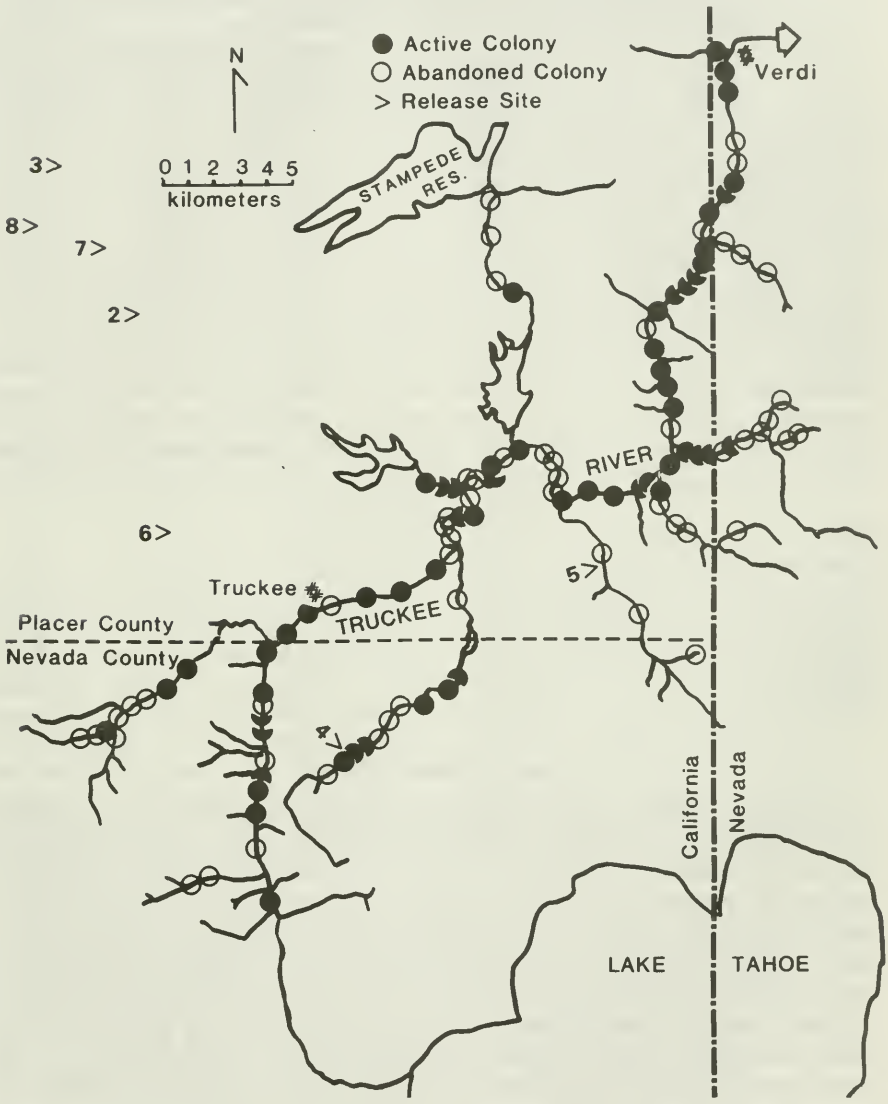

FIGURE 1. Location of active and abandoned beaver colonies in the Truckee River Basin, summer 1985. Release site numbers refer to Table 1; site 1 is south of Lake Tahoe. Streams not surveyed are omitted from the map.

TABLE 2. Length of Perennial Sample Reaches Surveyed, and Number of Reaches with Active Colonies (Group 1), with Abandoned Colonies (Group 2), Used but Uncolonized (Group 3), and Unused by Beaver (Group 4) for the Truckee River Basin, 1985. Numbers in Parentheses in Groups 1 and 2 Indicate Total Number of Colonies When This Exceeded Number of Reaches. For Tributaries, Either the Entire Stream or Its Lowest Portion was Surveyed, Except for Deer Creek and Juniper Creek (Headwaters Surveyed).

		number of reaches in group:			
Stream	*length (Km)*	*1 active*	*2 abandoned*	*3 used*	*4 unused*
Truckee River	53.8	34(39)	17(20)	13	0
Bronco Creek	12.1	4	1(2)	5	9
Sec 33 trib	1.6	0	1(2)	1	1
Davis Mdw trib	1.7	0	2(3)	1	0
Brush Creek	1.9	0	0	0	3
Cabin Creek	2.8	0	0	2	3
Canyon 24	1.0	0	0	1	0
Cold Creek	9.2	3	5	1	2
Emigrant trib	3.6	0	0	2	4
South Fork	4.7	0	1	2	4
Deep Canyon	5.3	0	3	1	5
Deer Creek	1.0	0	0	0	2
Gray Creek	7.0	1	3	3	4
North Fork	2.9	0	1	0	3
Juniper Creek	4.4	0	1(2)	5	1
Murphy Mdw trib	1.6	0	1	0	3
Little Truckee	5.6	1	3	1	0
Martis Creek	11.4	6(7)	4(5)	4	0
Sec 3 trib	0.1	0	0	0	1
Mystic Canyon	3.0	0	0	0	5
Pole Creek	5.0	0	2	1	5
Prosser Creek	2.2	3	0	1	0
Silver Creek	2.6	0	0	0	4
Sunrise Creek	1.7	1	0	0	2
Worn Mill Canyon	4.5	0	0	0	5
T17N,R16E s.29–32	2.4	0	0	0	5
T18N,R17E s.13	0.9	0	0	0	1
T18N,R18E s.19	0.5	0	0	0	1
Total	153.8	53(59)	45(53)	44	72

Use of Woody Plants

Cottonwood, aspen, willow, and alder were the most heavily used woody forage species (Beier and Barrett 1987). In locations where these species were rare, beaver made at least slight use of all woody species including serviceberry, snowbrush, mountain mahogany, *Cercocarpus betuloides*, gooseberry, and bitter cherry. Bitter cherry, for example, was very heavily cut on the Truckee River at 1645 m, where very little willow, and no aspen, remained. The only two woody species which did not show any beaver use were *Rosa* and *Artemisia*.

Conifers were cut in moderate amounts in all reaches used by beaver, and were used heavily where *Populus* and *Salix* were low in abundance. In rare cases, however, beaver made heavy use of conifers unrelated to depletion of favored forage species. For instance, at 1790 m on the Truckee River, every white fir over 10 cm dbh had been or was being cut by beaver, while much alder and willow, and some aspen, was left standing nearby. And on Cold Creek at 1935 m, lodgepole pine was heavily used in an area of abundant willow.

DISCUSSION

Beaver Distribution

From the eight original release sites, beaver have colonized many distant tributaries and have reached a density of 0.72 colonies/km on the Truckee River. This suggests that beaver are at or near their equilibrium density. Boyce (1981) reported a density of 0.63 colonies/km on a creek in Alaska, Collins (1976) reported 0.90/km in Wyoming, and Howard and Larson (1985) reported that 0.83 colonies/km appeared to approach equilibrium density in Massachusetts 30 years after beaver began to reoccupy their study area. The low beaver density on Truckee River tributaries (0.20 colonies/km), and the absence of beaver from some streams they once occupied, probably is because these streams provide relatively poor beaver habitat (Beier and Barrett 1987).

All beaver in the Truckee River Basin appear to have descended from at most nine founders. Because the Truckee River flows into Pyramid Lake, which has no outlet, and is separated from adjacent drainages by desert or by very rugged topography, gene inflow is unlikely. However, immigration may have occurred via two irrigation ditches which run approximately 40 miles from the lower Truckee River through desert to the Washoe and Carson drainages. Also, there may have been unauthorized releases of beaver into the Basin.

Use of Woody Plants

Taylor (1970) described heavy use by beaver of snowbrush and conifers when favored forages were depleted, and found that heavy use of snowbrush immediately preceded colony abandonment in one case. The heavy local use of conifers when normally-favored forages were still available has not been previously described, and was only rarely observed in this survey. This phenomenon may reflect the idosyncratic taste preferences of a few individuals, or localized need for a special nutrient found in the conifers. Alternatively, it may be due to chemical changes induced by herbivory on preferred species, making the normally-preferred plants less palatable to the herbivore. Such plant responses have been reported for willows browsed by hares, *Lepus americanus*, (Bryant et al. 1983), and for white birch, *Betula pubescens*, under heavy insect infestation (Haukioja 1980).

Given the broad range of forage species noted here and the ability of beaver to contribute to local extinction of favored species (Beier and Barrett 1987), it is tempting to speculate that beaver foraging may have played a role in the disappearance of the Truckee barberry, *Berberis sonnei*, from the Truckee Basin over the last several decades (Roof 1974). Only two populations of barberry were found during this investigation, despite diligent efforts to discover new populations. Clearly, the barberry has declined over roughly the same period as beaver have flourished. However, in 1985 fresh beaver debarking of cottonwood was noted less than 5 m from one of the extant clumps of barberry, which itself showed no sign of beaver browsing.

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LITERATURE CITED

Beier, P., and R. H. Barrett. 1987. Beaver habitat use and impact in the Truckee River Basin. J. Wildl. Manage., 51:794–799.

Bovce, M. S. 1981. Habitat ecology of an unexploited beaver population in interior Alaska. Pages 155–186 *in* J. A. Chapman and D. Pursley, eds. Worldwide Furbearer Conf. Proc.

Bryant, J. P., F. S. Chapin, and D. R. Klein. 1983. Carbon/nutrient balance of boreal plants in relation to vertebrate herbivory. Oikos, 40:357–368.

Busher, P. E. 1980. The population dynamics and behavior of beaver in the Sierra Nevada. Ph.D. dissertation. Univ. Nevada, Reno. 147 p.

Collins, T. C. 1976. Population characteristics and habitat relationships of beaver, *Castor canadensis,* in northwest Wyoming. Ph.D. thesis, Univ. Wyoming, Laramie. 188 p.

Hall, J. G. 1960. Willow and aspen in the ecology of beaver on Sagehen Creek, California. Ecology, 41:484–494.

Haukioja, E. 1980. On the role of plant defenses in the fluctuations of herbivore populations. Oikos, 35:202–213.

Hensley, A. L. 1946. A progress report on beaver management in California. Calif. Fish and Game, 32(2):87–99.

Howard, R. J., and J. S. Larson. 1985. A stream habitat classification system for beaver. J. Wildl. Manage., 49:19–25.

Lynn, A. V. 1949. Beaver transplanting. Final report project California 34-D-2. Calif. Dept. Fish and Game, unpubl. doc.

Roof, J. 1974. Found alive: the Truckee barberry. Four Seasons, 4:2–18.

Tappe, D. T. 1942. The status of beavers in California. Calif. Fish and Game Bulletin, 3:1–59.

Taylor, D. 1970. Growth, decline, and equilibrium in a beaver population at Sagehen Creek, California. Ph.D. dissertation, Univ. California, Berkeley. 162 p.

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NOTES

RECORD OF THE ROUGHSCALE SOLE, *CLIDODERMA ASPERRIMUM,* FROM NORTHERN CALIFORNIA WITH A NOTE ON THE PACIFIC LINED SOLE, *ACHIRUS MAZATLANUS*

Twenty-nine species of pleuronectiform fishes, representing the families Bothidae, Pleuronectidae, Cynoglossidae, and Soleidae (=Achiridae), are known from California (Hubbs, Follett, and Dempster 1979). We herein document the first known capture of the pleuronectid *Clidoderma asperrimum* (Temminck & Schlegel, 1846), the roughscale sole, from Californian waters. Secondly, we question the validity of the listing of *Achirus mazatlanus* (Steindachner, 1869), the Pacific lined sole (family Soleidae), as part of the State ichthyofauna.

Clidoderma asperrimum (Temminck and Schlegel, 1846)

On 12 January 1987 a single roughscale sole was taken by the MISS KELLEY I while fishing for Dover sole, *Microstomus pacificus* (Lockington), 28 nautical miles off Punta Gorda, Mendocino Co., California. The specimen was taken by bottom trawl in 550 fathoms. It measured 416 mm total length (TL) and weighed 985 g. While this note was in preparation a second California specimen was taken off Eureka, Humboldt Co., 19.5 nautical miles W of Humboldt Bay. This roughscale sole was taken on 23 March 1989 by the trawler DANDY BILL in 290 to 315 fathoms.

The occurrence of this Asiatic species (Jordan and Starks 1907 and Norman 1934), which is utilized commercially in Japan, is not totally unexpected off California. Records of the roughscale sole from British Columbia, Washington, and Oregon have been noted by Welander, Alverson, and Bergman (1957); Hubbs and Wilimovsky (1964); and Niska and Magill (1967). Quast and Hall (1972) included the roughscale sole in their "List of fishes of Alaska and adjacent waters . . . " but indicated that it was a species not recorded for Alaska waters. More recently, catch information for this species from the Bering Sea and the Aleutian Islands was provided to us by James Long, National Marine Fisheries Service, Seattle, and Alex E. Peden, British Columbia Provincial Museum, Victoria (pers. comm.), thus confirming the species from Alaskan waters. Also, in June 1973, a 430 mm TL roughscale sole was taken at lat 42° 08' N in 350 fathoms by the Dover sole trawler JEANNE ARAIN, 8 nautical miles N of the Oregon-California boundary. This specimen, as well as the example from Punta Gorda, is deposited at the California Academy of Sciences (CAS 35239 and CAS 60293, respectively). The Eureka fish is deposited at Scripps Institution of Oceanography (SIO 89–94). Selected measurements and counts for these three fish are given in Table 1.

TABLE 1. Counts and Morphometrics for California and Oregon Specimens of *Clidoderma asperrimum*

Locality	*Brookings*	*Eureka*	*Punta Gorda*
Counts			
Dorsal fin	88	84	88
Anal fin	70	67	71
Pectoral fin			
ocular side	14	13	14
blind side	—	12	—
Gill rakers	4+12=16	4+12=16	—
Morphometrics [1]			
Standard length	352	463	347
Total length	430 (122)	567 (122)	416 (120)
Head length	99 (28)	147.4 (32)	101.3 (29)
Snout length	24 (07)	—	26.2 (08)
Maxillae	21.5 (06)	40.4 (09)	25.3 (07)
Interorbital width	7.3 (02)	11.5 (02)	6.2 (0.2)
Orbit width	24.2 (07)	33.0 (07)	22.8 (07)
Longest gill raker	—	6.6 (01)	—
Pectoral length	53.0 (15)	60.0 (13)	51.5 (15)
Pelvic length	20.5 (06)	41.9 (09)	29.6 (09)
Caudal peduncle depth	35.0 (10)	39.1 (08)	30.7 (09)
Weight	—	302.5 g	98.5 g

[1] Measurements made on ocular side and given in millimetres. Figure in parenthesis represents percent of standard length.

The roughscale sole is easily distinguished from known Californian flatfishes. Diagnostic characteristics of the species are the presence of tubercles on the ocular side of which the larger are arranged in longitudinal series, blind side naked and darkly pigmented, lateral line with a slight arch above pectoral fin, and asymmetrical mouth (blind side much larger than ocular side).

Achirus mazatlanus (Steindachner, 1869)

In his "Marine Fishes of Southern California," Barnhart (1936) included *Achirus barnharti* with a diagnosis and figure of the species. Hubbs et al. (1979), in their "List of the Fishes of California," recorded *Achirus mazatlanus* under the family Achiridae. The basis of these two records is Jordan's (1923) description of *Achirus barnharti*. The species was represented by a single specimen collected "in about 400 feet depth" just north of the Coronado Islands, Baja California, Mexico. *Achirus barnharti* was treated as a junior synonym of *A. mazatlanus* by Hubbs et al. (1979) and there is no reason to question this action. The type-locality for *A. barnharti* falls within the limits of Mexican waters and to date no specimens of this flatfish have been taken farther north. Hence, it is reasonable and fitting to remove this sole (including the family Soleidae) from California's ichthyofauna until a bona fide specimen is collected.

LITERATURE CITED

Barnhart, P. S. 1936. Marine fishes of southern California. Univ. of California Press, Berkeley. 209 p.

Hubbs, C. L., W. I. Follett, and L. J. Dempster. 1979. List of the fishes of California. Occas. Pap. Calif. Acad. Sci., no. 133, 51 p.

Hubbs, C. L. and N. J. Wilimovsky. 1964. Distribution and synonymy in the Pacific Ocean, and variation, of the Greenland halibut, *Reinhardtius hippoglossoides* (Walbaum). J. Fish. Res. Bd. Canada. 21(5): 1129–1154.

Jordan, D. S. 1923. On the family of Achiridae or broad-soles, with description of a new species *Achirus barnharti* from California. Univ. Calif. Publ. Zool., 26(1):1–14, plate 1.

Jordan, D. S. and E. C. Starks. 1907. A review of the flounders and soles of Japan. Proc. U.S. Nat. Mus., 31(1484): 161–246.

Niska, E. L. and A. R. Magill. 1967. Occurrence of Greenland halibut and Asiatic flounder off Oregon. Research Briefs [Oregon]. 13(1): 123–124.

Norman, J. R. 1934. A systematic monograph of the flatfishes (Heterosomata). British Museum (Nat. Hist.), London. 459 p.

Quast, J. C. and E. L. Hall. 1972. List of fishes of Alaska and adjacent waters with a guide to some of their literature. NOAA Tech. Rept. NMFS SSRF-658.

Welander, A. D., D. L. Alverson, and P. Bergman. 1957. Rare fishes from the eastern North Pacific Ocean. Fisheries Research Papers. Wash. Dept. Fisheries. 2(1): 60–66.

—Robert N. Lea, Konstantin A. Karpov, and Lawrence F. Quirollo, California Department of Fish and Game, Marine Resources Division. (RNL - Marine Resources Laboratory - Granite Canyon, Coast Route, Monterey, CA 93940; KAK - 19160 South Harbor Drive, Fort Bragg, CA 95437; LFQ - 619 Second Street, Eureka, CA 95501). *Accepted for publication July 1989.*

Postscript—A third California specimen of roughscale sole was taken by the JENNA LEE south of Cape Mendocino in 500 fathoms on 22 November 1989.

STRANDINGS OF THE PACIFIC GIANT SQUID, *MOROTEUTHIS ROBUSTA* (VERRILL, 1876) (DECAPODA, CEPHALOPODA) IN BRITISH COLUMBIA

The Pacific giant squid, *Moroteuthis robusta* (Verrill, 1876), is considered abundant along the west coast of North America from Alaska to southern California (Hochberg and Fields 1980). Recorded from depths of 100 to 600 m, it is frequently taken by fishing trawlers off California (Smith 1963, Anderson 1978, Hochberg and Fields 1980). Although numerous captures and a few strandings of *M. robusta* have been reported from California and Oregon, there are few reports from British Columbia. Five specimens were trawled off the west coast of Vancouver Island in 1965 (Pattie 1968), and *Moroteuthis* sp. beaks have been reported in the stomachs of sperm whales captured off the coast of British Columbia (Robbins et al. 1937, Pike 1950, Clarke and MacLeod 1980). To my knowledge there are no published accounts of strandings of *M. robusta* in British Columbia.

Recently two specimens of *M. robusta* were found on beaches near Victoria, B.C. On 1 July 1986, a specimen measuring 3.21 m total length (TL) was found at Telegraph Cove on the east side of Vancouver Island, British Columbia (lat 48° 27.8′ N, long 123° 16.7′ W), by E. Petersen. The squid was changing color (opening and closing of chromatophores) suggesting it was recently stranded. Ten months later, on 4 May 1987, a specimen measuring 2.81 m TL was found by D. Shaw at Turgoose Point (lat 48° 36′ N, long 123° 23.2′ W), approximately 17 km north of the first stranding (Figure 1). Both specimens are now in the collection of the Royal British Columbia Museum (RBCM), catalogue numbers BCPM 986-115-1 and BCPM 987-33-1.

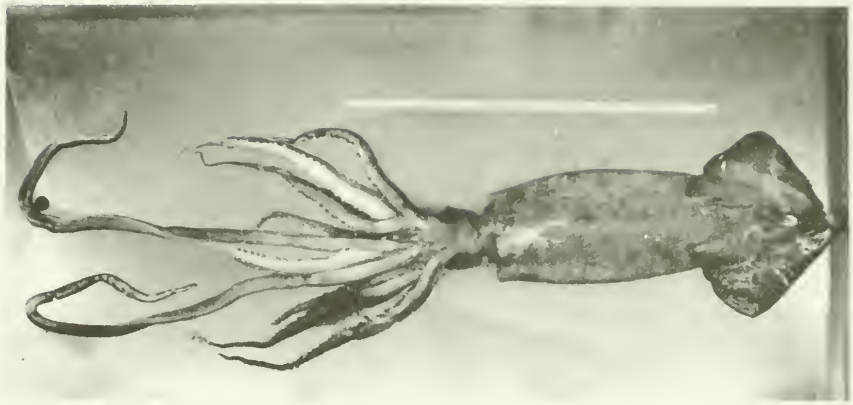

FIGURE 1. *Moroteuthis robusta* (BCPM 987-33-1), from Turgoose Pt. Vancouver Is., British Columbia

Measurements for both specimens are given in Table 1. Indices were calculated following Roper and Voss (1983).

$$\frac{\text{Character measurement}}{\text{Mantle Length}} \times 100 = \text{index}$$

Specimen 2 (BCPM 987-33-1) was measured immediately; specimen 1 (BCPM 986-115-1) was measured after one day in formalin. Indices were not calculated for incomplete arms.

TABLE 1. Measurements and Indices for *Moroteuthis robusta*.

Character	*Measurement (cm)*		*Index*	
	Specimen 1	*Specimen 2*	*Specimen 1*	*Specimen 2*
Total length	321.0	281.0	–	–
Mantle length	122.0	108.5		–
Mantle width	30.0	26.0	24.6	23.9
Fin length	63.5	57.5	52.0	52.9
Fin width	53.3	48.0	43.7	44.2
Head length	14.0	11.5	11.5	10.5
Head width	14.0	13.0	11.5	11.9
Arm I	66.0	47.0 *	53.7	–
Arm II	76.0	70.0	62.3	64.5
Arm III	63.0	67.0	56.1	61.7
Arm IV	57.0 *	66.0	–	60.8
Tentacle length	186.0	161.0	152.5	148.3
Club length	26.0	23.0	21.3	21.1

* arm incomplete

These strandings are significant because of the protected nature of the locations involved. Both strandings occurred in Haro Strait which lies between Juan de Fuca Strait and the Strait of Georgia, approximately 125 km from the open ocean.

Deep sea species have occasionally been reported in Juan de Fuca Strait and the adjacent Strait of Georgia. Barraclough and Waldichuk (1954) reported the capture of hatchetfish, *Argyropelecus lychnus,* viperfish, *Chauliodus macouni,* and a deep-water snailfish, *Careproctus melanurus,* in the waters of the southern Strait of Georgia. The RBCM also receives sporadic reports and specimens of deep sea species such as longnose lancetfish, *Alepisaurus ferox,* frostfish, *Benthodesmus simonyi,* and ocean sunfish, *Mola mola,* in Juan de Fuca Strait. At least one, apparently unreported, stranding of *M. robusta* has occurred in Haro Strait. The RBCM has recently acquired photographs from the collection of the late Dr. W. G. Fields, of a Pacific giant squid on San Juan Island in Washington State, approximately 10 km from Telegraph Cove where the 1986 stranding occurred. No date was recorded on the photographs.

The proximity of Juan de Fuca Strait to open water combined with strong tidal currents occasionally results in oceanic species being swept into the strait. Another factor contributing to the movement of animals into the strait is the flow of deep oceanic waters into Juan de Fuca Strait caused by the seaward flow of surface water from the Fraser River (Barraclough and Waldichuk 1954). Surface water removed from the strait is replaced by water from intermediate depths over the continental shelf, acting as an agent of transport for oceanic species entering the strait.

Literature Cited

Anderson, M.E. 1978. Notes on the cephalopods of Monterey Bay, California, with new records for the area. Veliger, 21(2): 255–262.

Barraclough, W.E. and M. Waldichuk. 1954. Offshore characteristics in the deep waters of the Strait of Georgia as indicated by bathypelagic fish. J. Fish. Res. Board Canada, 11(5): 501–506.

Clarke, M.R. and N. MacLeod. 1980. Cephalopod remains from sperm whales caught off Western Canada. Mar. Biol. (Berlin), 59:241–246.

Hochberg, F.G. and W.G. Fields. 1980. Cephalopoda: The squids and octopuses. Pages 429–444. *in* R.H. Morris, D.P. Abbott and E.C. Haderlie, eds. Intertidal invertebrates of California. Stanford Univ. Press, Stanford, Calif.

Pattie, B.H. 1968. Notes on giant squid *Moroteuthis robusta* (Dall) Verrill trawled off the southwest coast of Vancover Island, Canada. Washington Dept. Fish. Res. Pap., 3:47–50.

Pike, G.C. 1950. Stomach contents of whales off the coast of British Columbia. Fish. Res. Bd. Canad., Prog. Rept. Pacific Coast Sta., 83:27–28.

Robbins, L.L., F.K. Oldham, and E.M.K. Geiling. 1937. The stomach contents of sperm whales caught off the west coast of British Columbia. Rept. Prov. Mus. Natur. Hist. British Columbia, p. 19–20.

Roper, C.F.E. and G.L. Voss. 1983. Guidelines for taxonomic descriptions of cephalopod species. Pages 49–63 *in* C.F.E. Roper, C.C. Lu and F.G. Hochberg eds. Proceedings of the workshop on the biology and resource potential of cephalopods. Memoirs of the Nat. Mus. of Victoria, Vol. 44.

Smith, A.G. 1963. More giant squids from California. Calif. Fish and Game, 49(3): 209–211.

—Gordon Green, Biology Section, Royal British Columbia Museum, Victoria, B.C. Canada V8V 1X4. *Accepted for publication May 1989.*

NEW MAINLAND HAUL-OUT SITE FOR THE NORTHERN ELEPHANT SEAL, *MIROUNGA ANGUSTIROSTRIS,* IN CENTRAL CALIFORNIA

This note documents the use of a new haul-out site by the northern elephant seal, *Mirounga angustirostris* Gill. This site is on the mainland of the central California coast next to a man-made breakwater which protects the water intake structure for an electric-generating power plant. We describe the features of this new site and include some changes in abundances over time, although additional information is currently being gathered.

The near demise of the northern elephant seals from exploitation by commercial sealers in the 1800's resulted in a minimum population of less than 100 animals on Isla de Guadalupe, Baja California, Mexico in 1892 (Bartholomew and Hubbs 1960). The Mexican government protected the species in 1922 (Bartholomew and Hubbs 1960) and the United States followed suit a few years later (Le Boeuf and Panken 1977). The population has grown steadily, evidenced by increasing numbers of seals at established rookeries and colonization of new sites (Cooper and Stewart 1983).

The current documented breeding range is from Isla de Natividad, Baja California, Mexico to the Farallon Islands, California (Campbell 1987). In recent years, as island colonies have increased in numbers, mainland sites have been colonized by reproductive seals at the Point Reyes Peninsula (Allen, Peaslee, and Huber 1987), Año Nuevo Point (Le Boeuf and Panken 1977), Point Saint George (Bonnell, Pierson, and Farrens 1983), and Cape San Martin along the Big Sur coastline (Bonnell et al. 1983). In addition, small numbers of immature elephant seals haul out seasonally along the coasts of northern California and Oregon (Hodder and Graybill 1985, Griswold 1985), and along the central California coast near Grimes Point (R. Jameson, U.S. Fish and Wildlife Service, pers. comm.) and Point Arguello (Bonnell et al. 1983).

A mainland haul-out site has recently been documented inside a man-made harbor at the Diablo Canyon Power Plant, San Luis Obispo County, California (lat 35°12'30" N, long 120°51'15" W; Figure 1). The power plant is located approximately 20 km W of San Luis Obispo on a 300 ha site isolated from public access. The haul-out site is unique because of its close proximity to the power plant's water intake structure inside man-made breakwaters. The two breakwaters are composed of 23,000–30,000 kg, three-sided, concrete tri-bars which protect the cooling-water intake structure from the prevailing northwesterly ocean swells.

The haul-out location is on the leeward side of the west breakwater and encompasses an area of approximately 100 m^2. The haul-out area was subdivided into three sections for observations; the preferred haul-out area extended from water level to an elevation of about 8 m (Figure 1, Area A). This area was about 14 $\times$ 2 m in size and consisted of rocks and boulders (Figure 2). A small cave extending back 2 m was used occasionally by two to three animals. A secondary haul-out area (Figure 1, Area B) was on a level concrete area, which extended into the intake cove and which, except at low tide, was covered with water. An adjacent, smaller area of bedrock (Figure 1, Area C) was also used when the primary areas were crowded.

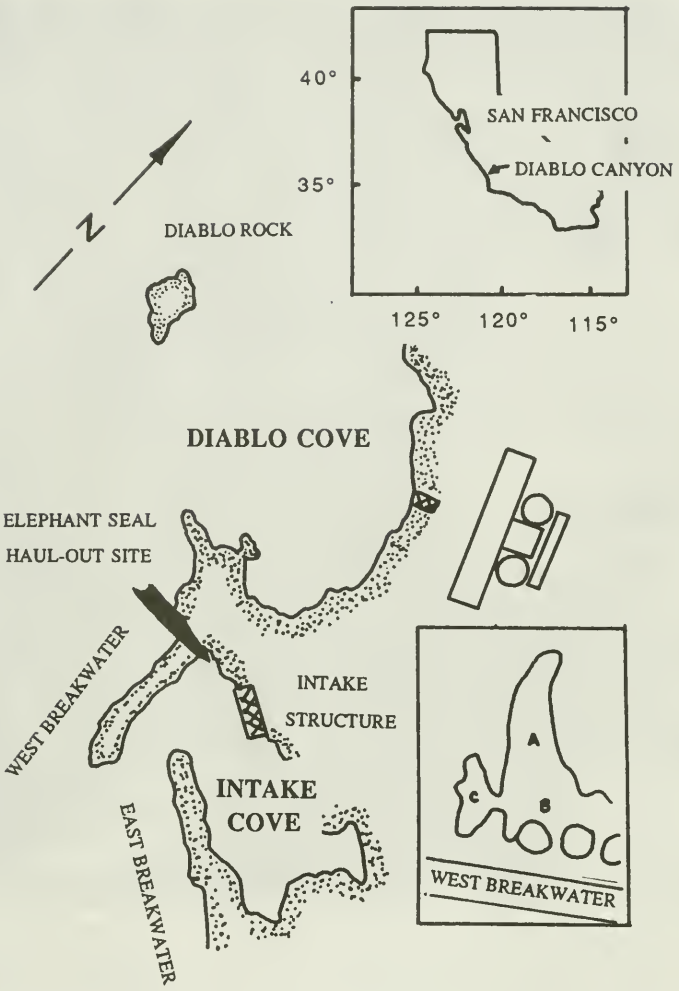

FIGURE 1. Location of the haul-out site near the Diablo Canyon Power Plant, central California.Inset shows the primary haul-out area (A) and secondary haul-out areas (B and C).

There have been sightings of individual elephant seals hauled out on beaches in the Diablo Canyon area since 1978 (S. Benech, Benech Biological Associates, pers. comm.). The first sightings of elephant seals using the intake cove haul-out area were made in December 1986. We began studies of this group of immature seals in September 1987. Total numbers of seals, number of tagged seals and their tag color, tag location and tag numbers, sexes (when possible), and approximate sizes of seals were recorded.

FIGURE 2. Main haul-out area on the inside of the west breakwater (view towards the northeast). Note the rocks and boulders in the area, the power plant cooling-water intake structure in the background and the tri-bar breakwater material in the foreground. The face of each tri-bar is about 1.2 m across for scale. Photo by Joyce True.

Daily total counts of animals utilizing the site varied from a maximum of 57 in early October, 1987 to zero in February–March 1988. All individuals appeared to be immature animals from 1.5 to 2 m in standard length, visually estimated from tip of nose to tail. Seals of both sexes were seen, but the sex could not often be determined because most seals were on their ventral side. Twenty-eight individually tagged animals were observed. Nineteen were tagged on San Miguel Island, five on San Nicolas Island, three on the Farallon Islands, and one animal was tagged at the Marine Mammal Rehabilitation Center at Fort Cronkhite, California. No animals tagged at Año Nuevo were sighted at Diablo Canyon. Eighty-seven percent of the tagged animals were from the Channel Islands.

Based on our observations, we predict that animals will consistently return in fall, leave for a short time, then return in the spring to use the site while molting and resting. We do not anticipate that the Diablo Canyon site will become a breeding or pupping site since space is limited. However, nearby sandy beaches could become utilized as haul-out or breeding areas in the future. We expect the Diablo Canyon site to be continually utilized in the future on a seasonal basis as an elephant seal transitory and molting site.

We thank Pacific Gas and Electric Company for their support of this study. We also thank D. Hanan and B. Stewart for their kind assistance and recommendations. D. Behrens, J. Carroll, R. Massengill, and B. Stewart reviewed early drafts of this paper, and L. Hall helped collect data.

LITERATURE CITED

Allen, S. G., S. C. Peaslee, and H. R. Huber. 1987. A colony of northern elephant seals on Point Reyes Peninsula, California. Final Report to the Point Reyes–Farallon Islands National Marine Sanctuary, Sanctuary Programs Office, National Oceanic and Atmospheric Administration.

Bartholomew, G. A. and C. L. Hubbs. 1960. Population growth and seasonal movements of the northern elephant seal, *Mirounga angustirostris*. Mammalia, 24:313–324.

Bonnell, M. L., M. O. Pierson, and G. D. Farrens. 1983. Pinnipeds and sea otters of central and northern California, 1980–1983: status, abundance, and distribution. Pages 161–171 *in*: Marine mammal and seabird study, central and northern California. Vol. III, Investigator's Final Report, part 2. Minerals Management Service, U.S. Dept. of Interior. Contract NA. AA-551-CT9-33.

Campbell, R. R. 1987. Status of the northern elephant seal, *Mirounga angustirostris* in Canada. The Canadian Field-Naturalist, 101(2):266–270.

Cooper, C. F. and B. S. Stewart. 1983. Demography of northern elephant seals, 1911–1982. Science, 219:969–971.

Griswold, M. D.,Jr. 1985. Distribution and movements of pinnipeds in Humboldt and Del Norte Counties, California. Abstr. Sixth Bienn. Conf. Biol. Mar. Mamm. Vancouver, British Columbia, Canada. 22–26 November 1985.

Hodder, J. and M. Graybill. 1985. Regular use of a haul-out site in southern central Oregon (43°20'N) by northern elephant seals. Abstr. Sixth Bienn. Conf. Biol. Mar. Mamm. Vancouver, British Columbia, Canada. 22–26 November 1985.

Le Boeuf, B. J. and K. J. Panken. 1977. Elephant seals breeding on the mainland in California. Proc. Calif. Acad. Sci., 41(9):267–280.

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BOOK REVIEWS

ABALONE: GROSS AND FINE STRUCTURE

by Gerrit Bevelander. 1988. Boxwood Press, Pacific Grove, CA. 80 p. $18.00

This small paperback volume, consisting primarily of photomicrographs of histological preparations of the tissues and organ systems of abalone, is a much needed and useful addition to the literature on abalone. As the author points out in his preface, detailed histological information on abalone is practically nonexistent. Indeed, one might go further and suggest that such information is generally hard to find for most gastropods. This small volume might well serve as a model for other such investigations for other molluscan groups.

The book is divided into ten chapters: Introduction, Development, External Features, Shell, Mantle Cavity, Digestive System, Nervous System, Circulatory System, Urinary and Reproductive Systems, and Foot, Skin and Tissues. There is also a short General References section and a more extensive Bibliography, which should more correctly be labeled Literature Cited.

My only complaint with the general organization of the book is the placement of the chapter on Foot, Skin and Tissues as the last chapter of the book. Since biology generally covers tissues before organ systems, it would seem to this reviewer more logical to have placed this chapter right after External Features.

The General References section I interpreted to be an attempt by the author to provide a brief list of some more pertinent and detailed books of basic gastropod biology. If this was the intent, then I would certainly suggest this section needs revision. The two-volume 1966 edition of the *Physiology of the Mollusca,* edited by Wilbur and Yonge, cited by the author is out of print and, furthermore, has been superseded by the new and more complete 12-volume series, *The Mollusca,* edited by Wilbur (1983–1988, Academic Press). I would also add *A Functional Biology of Marine Gastropods* by Roger Hughes (Johns Hopkins, 1986), and the *Treatise on Invertebrate Paleontology I, Mollusca 1,* as significant for background information. I also think that any reference list for abalone should include Cox's paper "California Abalone, Family Haliotidae" (Fish Bulletin No. 118 of the Calif. Dept. of Fish and Game, 1962).

In general, the book is well done and quite complete. The photomicrographs and their labels are reproduced in very clear detail. The text is brief, but complete, and very readable. I found relatively few mistakes, and most were minor typos. Perhaps the most serious was on p. 15 where the author says the mantle cavity contains the "genital apertures"; but what he means is the renal apertures, since the gonad is single and exists via the right kidney.

This book is useful, needed, relatively inexpensive by today's book prices, and should find its way into the libraries of all those interested not only in abalone but also in the histology of gastropods in general.

—James Nybakken
Moss Landing Marine Laboratories

SEA OF CORTEZ MARINE INVERTEBRATES, A GUIDE FOR THE PACIFIC COAST, MEXICO TO ECUADOR

by Alex Kerstitch. 1988. Published by Sea Challengers, Monterey, CA. 120 p. $21.50 paper.

The Sea of Cortez has long attracted the interest of marine biologists, since the early expedition of the Steamer Albatross (1891), the exploration of Diguet (1895), various expeditions of the California Academy of Sciences (1905 and 1922), the Allan Hancock Pacific Expeditions (1932–1954), and the well documented exploits of Ed Ricketts and John Steinbeck. Many scientific papers have been published describing the rich biota of the Gulf but few attempts have been made to provide a field guide to the invertebrates of the region. In 1968, Wes Farmer provided *Tidepool Animals of the Gulf of California,* a first step in popularizing the invertebrate life inhabiting the Gulf's waters. Rick Brusca (1973 and 1980) greatly enhanced the professionalism of our knowledge of the biota with two editions of his *Common Intertidal Invertebrates of the Gulf of California.* Dan Gotshall (1982) provided the first pictoral field guide to the fauna, which included many invertebrates. The present work represents yet another milestone in the summary of the common invertebrate fauna of the Gulf of California.

Alex Kerstitch has been studying and photographing the marine fauna of the region. His many years of investigation have provided a visually stunning and scientifically valuable contribution that

is useful to scientists and casual visitors alike. Kerstitch has been aided by three major contributors, Hans Bertsch, L. Yvonne Maluf, and Ron McPeak. Many other individuals contributed to the editing and reviewing of the text.

An uninformed reader might be confused by the title, thinking that the Sea of Cortez extends from Mexico to Ecuador. Though many, if not most, of the organisms found in the Sea of Cortez are found throughout the Panamic Biogeographic Province (extending as far south as Peru or northern Chile) the book is designed as a field guide to the invertebrate fauna of the Gulf of California. Mention of these issues, with the addition of a map, would have helped clarify these points. The brief introduction is followed by a short section on how to use the book. This is followed by a rather abrupt discussion of major phyla, with no real transition. The pictoral key to phyla is not really a key, nor does it deal exclusively with phyla. It includes some groups as phyla, others that are classes, and still others which are orders. Nevertheless, the layman may find this a useful way to start to look for an unusual invertebrate.

The remainder of the book provides a striking display of invertebrates most of which were caught in the act of feeding, crawling, swimming, or reproducing. It is exceedingly difficult to capture organisms in the field in a manner that illustrates them in a natural habitat yet still permits them to be readily identified from the photograph. Kerstitch and the other photographers are to be congratulated for this achievement. One is even treated to a photograph of the author wrestling a giant squid. Only a few photographs have been staged in aquaria or on uniform background.

Correct identification of species and keeping up with the ever changing taxonomy of groups as diverse as the invertebrates are difficult undertakings. Only a few minor glitches appear to have made their way into the text. The sea anemones listed as species of *Tealia* are now placed in the genus *Urticina*. Unfortunately, two nudibranch species have been misidentified. The animal listed as *Flabellina telja* is rather an undescribed species of *Flabellina* and *Baeolidia nodosa* is in fact *Berghia major*. Rather than inventing common names that are not particularly useful to either the scientist or layman, it would have been better to list the author and date of authorship for each species.

It is easy to find fault with any work, particularly one that attempts to bridge the gap between professional and popular audiences and one which covers such a broad range of organisms. Despite some minor shortcomings, this book achieves the author's goal. It is a major advance in making the rich biota of the Sea of Cortez known to biologist, fisherman, beachcomber, and underwater photographer. It is the sort of book that I will turn to often. I am sure that my copy will end up being well worn and covered with salt. That is the best measure of the usefulness of a book. Just thumbing through the pages makes me want to pack my diving gear and head south to the exotic realm of the Sea of Cortez again.

—Terrence M. Gosliner
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